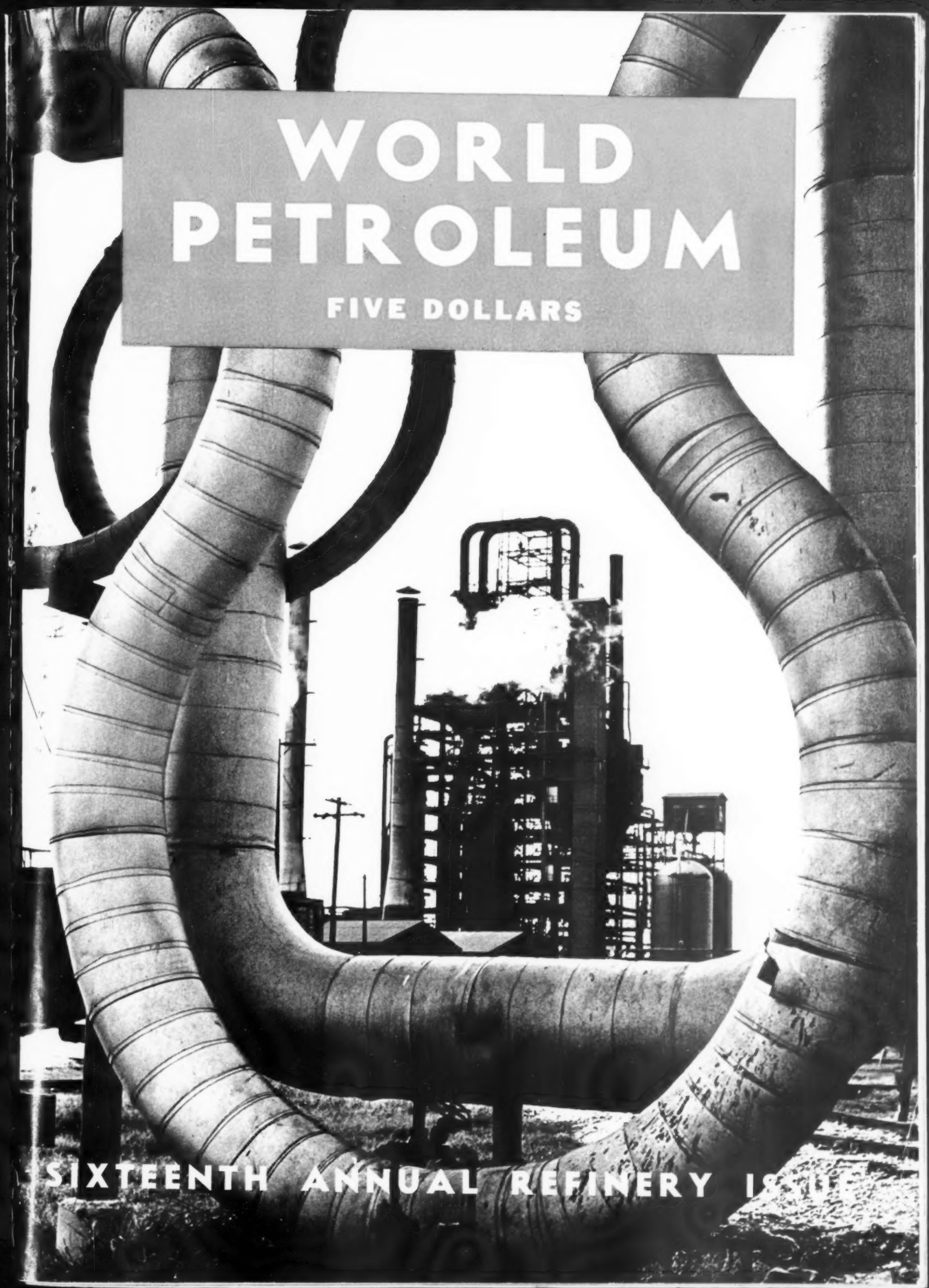
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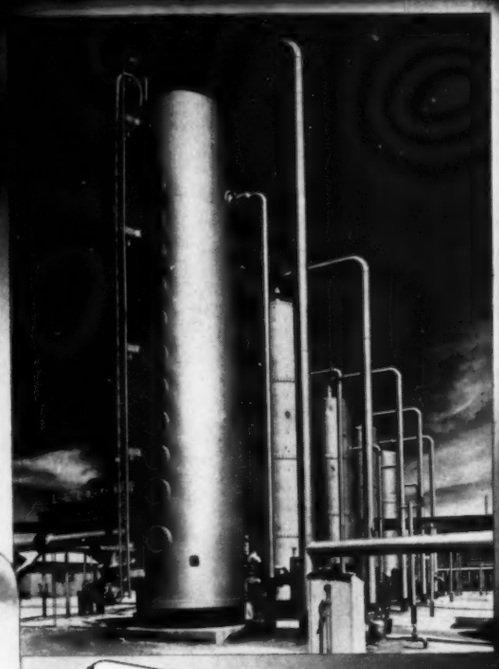

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CONTENTS

VOLUME 17 REFINERY, 1946 NUMBER 8

Refining Industry Entering New Era of Expansion 51

Production of Gasoline from Natural Gas 52

Restoration Work at Palembang 55

Oil Companies Extend Operations 58

Modern Catalytic Processing in Summary 60

Catalytic Cracking for the Small Refinery 63

Small Kellogg Fluid Cat-Cracker 64

Small Thermofor Cat-Cracker 66

Small UOP Cat-Cracking Unit 68

Cycloversion for the Small Refiner 70

A British Refinery in Wartime 71

Abadan's Wartime Expansion 74

Refinery Construction 78

Indiana Standard's Three Cat-Cracking Units 82

Naphtha Fractionator for Feed Prepartion 84

Demand Forecast for Petroleum Products 87

Developments in Lube Oil Manufacture 94

COVER: Fluid Catalytic Unit No. 2 at Humble Oil & Refining Co. Plant, Baytown, Texas.

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EDITORIAL

REFINING INDUSTRY ENTERING NEW ERA OF EXPANSION

In mid-year 1946 the situation in the refining industry presents a striking contrast with that prevailing at any previous time in the past half-decade. A year ago the energies of refiners were concentrated on producing high-octane gasoline and other products for the armed forces of the United Nations in a volume never before approached. The war itself was approaching its close but that, of course, was unknown either to the men at the front or to those on the production line at home and two million barrels of oil were being processed daily to meet the needs of the armed forces.

Today, ten months after the close of hostilities, refiners have readjusted their operations to the satisfaction of peacetime demands. Conditions attending these operations, however, are markedly at variance with the forecasts prepared by economists and statisticians of the industry prior to the conclusion of the war. It was assumed, with every appearance of sound reasoning, that with an abrupt drop in military requirements a sharp decline would take place in the demand for petroleum products. In the United States, with the number of motor vehicles in operation computed at four to five million less than in 1941, it appeared evident that the consumption of gasoline would be correspondingly reduced. With thousands of industrial plants facing the necessity of changing their equipment and their products the use of fuel oil and lubricants seemed destined to be similarly affected though perhaps in less degree. In Europe, second largest of the world's markets, the almost complete disappearance of road vehicles and farm machinery in countries subjected to Nazi occupation, the disruption of transportation and the general industrial and political disorganization foreshadowed a period of slow and painful recovery before anything like normal demand could be restored. In other parts of the world similar obstacles to trade restoration were shown to exist.

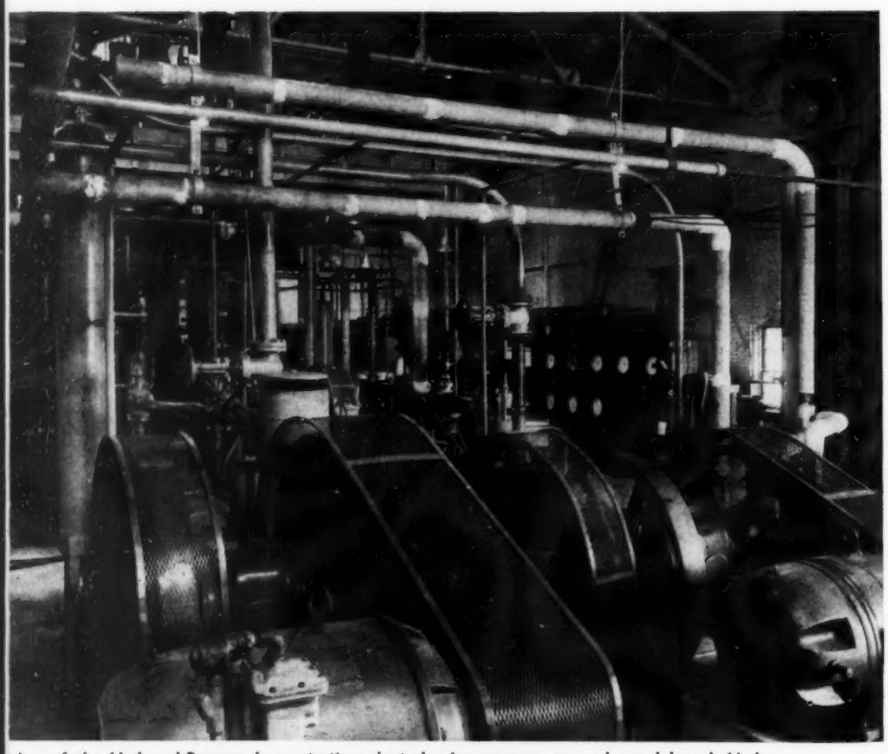
It was recognized that these conditions were temporary but in the opinion of experienced observers the period of lessened activity was certain to be acute during 1946 and to continue in diminishing degree until 1950 which was set as the earliest date at which the pre-war scale of activity could be resumed. So widely accepted were these convictions that producers were warned to reduce their output of crude and state regulatory bodies cut allowables to avoid the accumulation of unmanageable stocks until upward revisions were forced by threatened shortages in various directions.

Contrary to logical expectations crude production has had to be maintained at a high level to meet current demand and at one point exceeded the peak of wartime output. While few new motor cars have been produced the consumption of gasoline has run close to the average of the war years and the demand for distillate fuels has been higher than when the military struggle was under way. American refineries have been working at near capacity except in cases where they have encountered difficulty in obtaining adequate supplies of crude. At the same time imports have increased by 40 percent over their 1945 level.

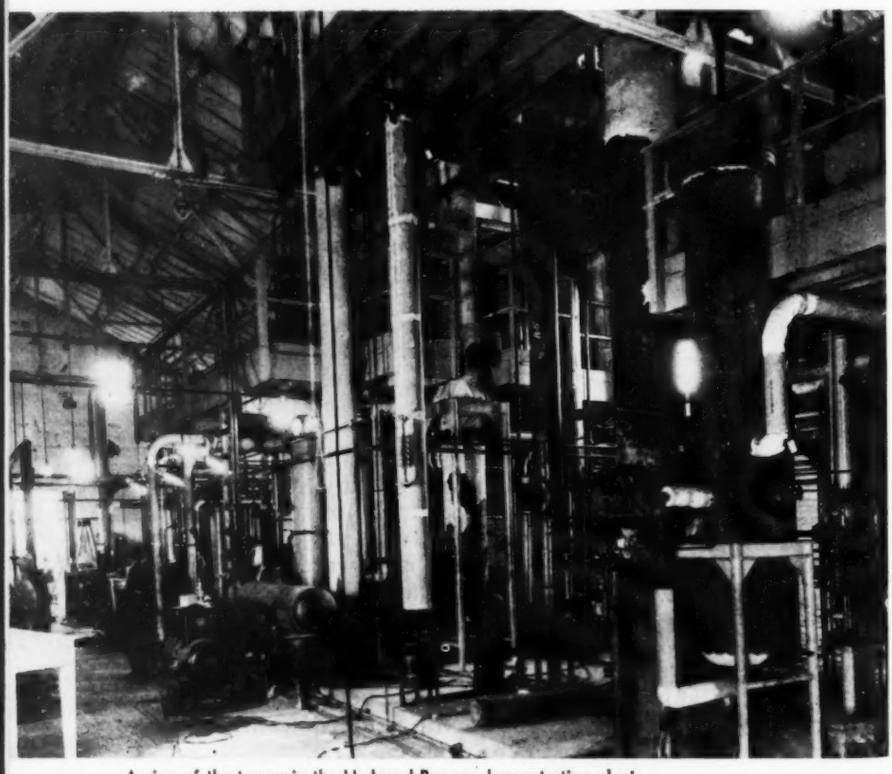
Oil men themselves have been at a loss to explain the sustained demand for their products despite the interruptions to industrial production. The explanation seems to lie in the fact that while the number of motor cars may be less than before the war the mileage of those remaining is higher, particularly in the case of buses and trucks, that a backed-up demand for fuel oils is finding expression and that new uses for oil products and a fuller appreciation of their essential importance in industrial progress has resulted from the experience of the past few years. Depending upon economic conditions there seems to be a reliable prospect that instead of retracing the steps that it has taken during the war period the expansion of the industry will go forward from the new and higher level of operation that has been established.

As in the demand for products so also in the extension of refining facilities activities are far exceeding earlier expectations. Instead of a lull in plant expansion in the United States anticipated as a result of the huge building program carried out during the war new construction and projected additions to existing refineries involve a capital expenditure nearly double that of the most active of pre-war years. In the rest of the world the necessity of repairing the damage inflicted by air and land assaults in which oil installations were preferred targets, together with the development of new fields and shifts in trade relations, have inspired a volume of present and projected construction activity entirely without precedent. Unavoidable delays in obtaining materials and in providing transportation are the present limiting factors upon this world-wide forward movement. Viewing the international picture as a whole it is clear that the refining industry is entering a new era of expansion which will tax the facilities of equipment manufacturers for years to come.

PRODUCTION OF GASOLINE FROM NATURAL GAS



view of the Hydrocol-Process demonstration plant showing compressors and panel board, Hydrocarbon Research, Inc., Olean, N. Y.



A view of the towers in the Hydrocol-Process demonstration plant.

ONE of the most noteworthy, perhaps the most significant, development in the current progress of refining is the inauguration on a commercial scale of the recovery of gasoline from natural gas. It is signalized by the erection of a plant, the first of its kind in the world, construction of which will be started soon in Texas. The plant is to be erected by Carthage Hydrocol Inc. at an estimated cost of $15,000,000, utilizing processes and engineering design developed by Hydrocarbon Research Inc. It is scheduled for completion late in 1947.

It is highly appropriate that the inception of this revolutionary undertaking should occur at a time when the value of natural gas as a natural resource and the necessity of its conservation is attracting greater attention than ever before in the United States. Some measure of its importance is afforded by the fact that present known reserves, if converted into gasoline or related products, would double the calculated petroleum reserves of the country, now estimated at roundly 20,000,000,000 barrels. Because of its many other valuable applications it is not to be anticipated that natural gas will be devoted entirely to the production of motor fuel but the development of the Hydrocol process provides a means of turning to profitable employment deposits that are not supplied with long distance transportation facilities.

Some misunderstanding of the Hydrocol process has resulted from its identification in popular discussion with the Fischer-Tropsch process originated in Germany. It is true that the underlying principle of the synthesis of oil from a mixture of carbon monoxide and hydrogen was discovered through studies made by Fischer and Tropsch a quarter of a century ago. These two scientists worked with materials available in Germany, coke and braunkohle. Steam treatment was used to break down the materials to the carbon monoxide-hydrogen combination and a catalyst was found which effected the desired synthesis with the addition of oxygen. A number of plants utilizing this method were built in Germany during the thirties and they contributed a substantial part of the motor fuel and oil used by the Germans during the war.

PROMISES GREAT INCREASE IN POTENTIAL RESERVES

The synthetic industry was not commercially competitive with natural petroleum but since Germany's oil fields were able to supply only a small part of the country's requirements and the main objective of the government was to increase the production of liquid fuel and lubricants within the country's own borders, subsidies were provided to maintain synthetic plants in operation, both those employing the Fischer-Tropsch system and others.

Research in the field of synthesis was, of course, active in the United States long before the war though here it was directed mainly to increasing recovery or improving the quality of products derived from crude oil. American investigators were faced by the necessity of devising means of meeting the competition of natural petroleum and it was not until the huge demands imposed by the war directed attention to the desirability of expanding utilizable reserves that the problem was attacked in real earnest from this angle.

It was then that Hydrocarbon Research Inc. was organized by P. C. Keith, an engineer of long experience in the design and engineering of oil refineries, chemical plants and, as vice president of Kellex Corporation, in the creation of the gas diffusion section of the Oak Ridge plant where the A-bomb was developed. With the co-operation of Clark Bros. Co., of the Dresser Industries group and the financial backing of Socony-Vacuum Oil Company, J. S. Abercrombie and La Gloria Corporation a laboratory and pilot plant was established at Olean, New York. Here active experimentation was carried on with the goal of evolving commercially practicable methods of obtaining synthetic products on a basis that would be competitive with high grade fuels made from crude oil in existing refineries. Natural gas was selected as the most promising raw material because of its abundance and relative cheapness. By direct burning of the gas in oxygen the process that had been used in Germany was greatly simplified and the cost of equipment and operation reduced. A simplified method of separating oxygen from the air was another feature of the development and the selection of an efficient and abundant catalyst was another factor. As the evolution of the process progressed The Texas Company and Standard Oil Development Company whose research organizations had carried on investigations in the same fields made the results of their studies available to Hydrocarbon Research thereby contributing to the development of the process.

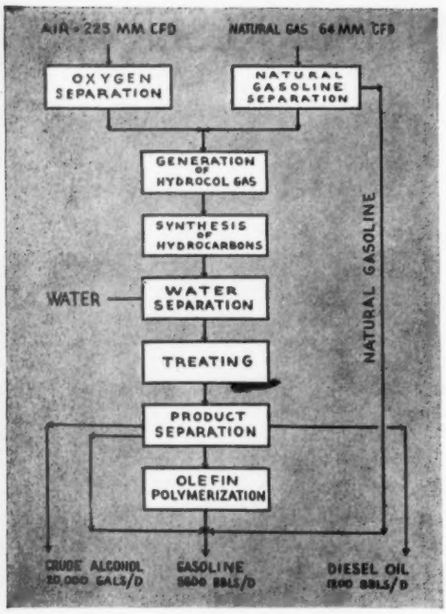
As finally accepted as the result of pilot plant operation, the Hydrocol Process includes the separation of high purity oxygen from air, the combustion of natural gas with the oxygen to produce a mixture of carbon monoxide and hydrogen, designated as Hydrocol gas, the conversion of this gas under catalytic treatment into gasoline and other synthetic products, the separation of the gasoline and other products by fractionation and the treatment of the gasoline to remove oxygenated compounds, polymerization of the propylene and butylene, and other established refining steps.

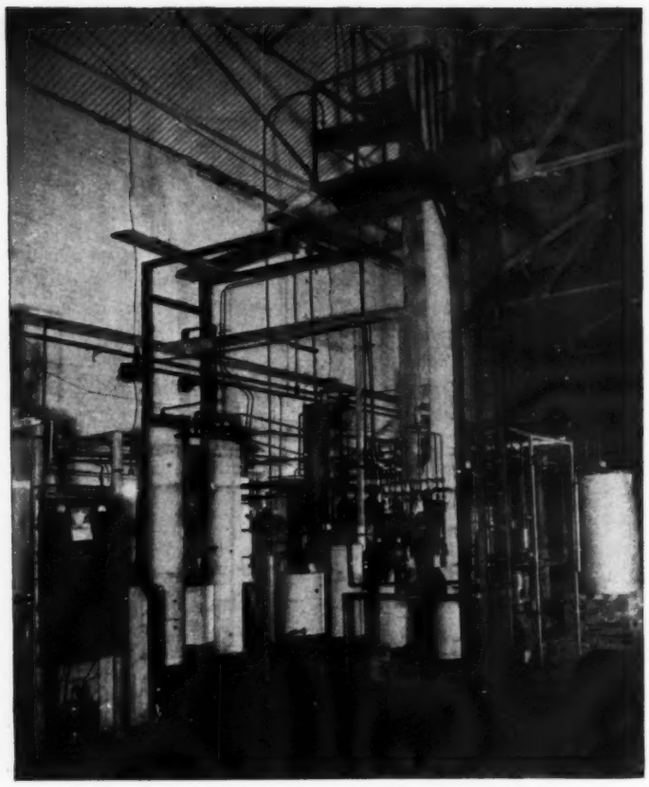
It was calculated on the basis of the pilot plant operation that a large scale plant would be able to produce high quality gasoline, allowing credit for by-products at a manufacturing cost of 2.5 cents a gallon and an overall cost, including interest, depreciation and amortization, of 5.25 cents a gallon. This is considered to be approximately equal to the cost of production of gasoline of like quality from crude oil in the Gulf Coast area. An improvement on this showing is considered possible from increased capacity and a reduction in capital costs that may come with further experience.

Having arrived at the stage where commercial operation was considered feasible the logical next step was the formation of a company to erect and operate a large scale plant employing the Hydrocol process. This was accomplished through the organization of Carthage Hydrocol Inc., in which The Texas Company, Hydrocarbon Research, Inc., Niagara Shares Corporation. Forest Oil Corporation, La Gloria Corporation, United Gas Company, Stone & Webster, Chicago Corporation and Gulf State Oil Company are stockholders. The name Carthage was included in the title because it originally was planned to locate the plant in or near the Carth-

P. C. Keith, President, Hydrocarbon Research, Inc.

Experimental oxygen plant of Hydrocarbon prior to insulation.





Experimental pilot plant.

age gas field in East Texas. Further consideration of a long term supply of gas not preempted for other purposes led to the selection of South Texas, as a preferable location. Gas will be supplied under 20-year contracts by United and La Gloria through a pipe line to be constructed for this purpose. Evidence of the financial soundness of the project as viewed in official circles is afforded by the fact that the Reconstruction Finance Corporation has granted a loan of $9,000,000 to the company. The owners have subscribed $10,000,000 thus making a total of $19,000,000 available to the project.

While references has been made in the foregoing only to the production of gasoline from natural gas the Hydrocol process is not confined to this one product. It is highly flexible but in the program projected for this first commercial plant end products will be limited to gasoline, diesel oil and alcohols. According to design the plant will process 64,000,000 cubic feet of natural gas per day and will deliver 5,800 barrels of 80 octane gasoline, 1,200 barrels of diesel oil and 20,000 gallons of crude alcohols including ethyl, propyl, butyl, amyl and heavier alcohols. Three vital steps, each of which represents a great advance over previous knowledge and practice, are involved in the Hydrocol process. The first of these is the method employed in the separation of oxygen; the second is the synthesis of gas under high pressure and temperature; the third is the catalytic reduction of the Hydrocol gas into desired products.

Equipment for most of the plant operations has its counterpart in conventional refinery operations, as for example, fluidized powdered-catalyst type of reactors, poly unit, fractionators, stabilizers, and product recovery and treating equipment. Unlike conventional refinery operations, however, and involving a marked departure therefrom, is the provision for continuously operated low pressure oxygen-separating units and high pressure Hydrocol-gas generators. The oxygen separating units will be the largest ever built. With compression to 75 pounds they will produce a total of 40,000,000 cubic feet of oxygen per day at an estimated cost of 4.8 cents per M.

An outstanding feature of the plant will be the generators in which preheated natural gas and oxygen will be reacted at 250 pounds pressure and at high temperature to produce the carbon monoxide and hydrogen mixture known as Hydrocol gas, which in turn is converted to the desired synthetic products in the fluidized-catalyst reaction chambers.

Directors of Cathage Hydrocol Inc. are P. C. Keith, president of Hydrocarbon Research, Inc.; H. N. Mallon, president of Dresser Industries, Inc.; Harry T. Klein, president, The Texas Company; Michael Halpern, vice-president, The Texas Company; Richard J. Dearborn, president, Texaco Development Corporation; G. H. Clifford, vice president, Stone & Webster, Inc.; Guy George Gabrielson, president and general counsel, Carthage Hydrocol, Inc.; John F. Lynch, vice president, La Gloria Corporation; W. Frank Miller, vice president, Forest Oil Corporation; and J. F. Schoellkopf IV, vice president of Schoellkopf, Hutton and Pomeroy, Inc.

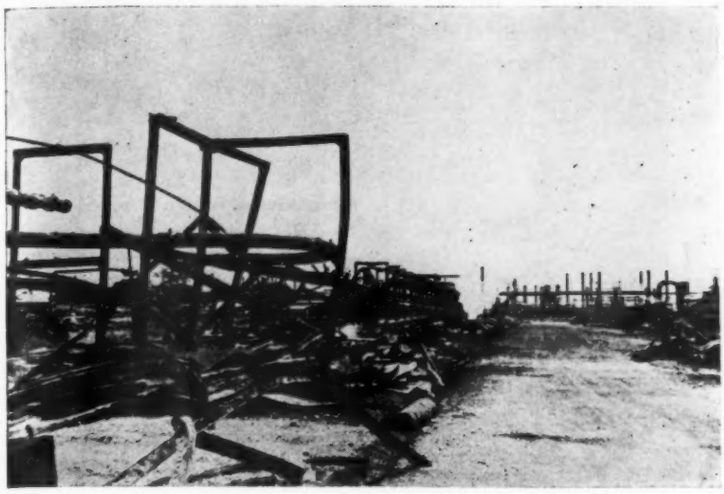
The engineering methods developed by Hydrocarbon Research, Inc., are as applicable to the production of synthetic petroleum products from shale or coal as from natural gas. One of its promising future applications is the gasification of coal which may make it possible for city gas companies to pipe their finished product direct from the centers of coal production doing away with costly steam plants which they are now compelled to maintain and greatly reducing the heavy transportation charges on the shipment of coal in bulk. Pilot plant experiments on this subject and on numerous other applications are now being conducted by Hydrocarbon Research, Inc. Texaco Development Company is working intensively with HRI in all its research activities and will act for it in licensing the Hydrocol process in the oil industry.

◆

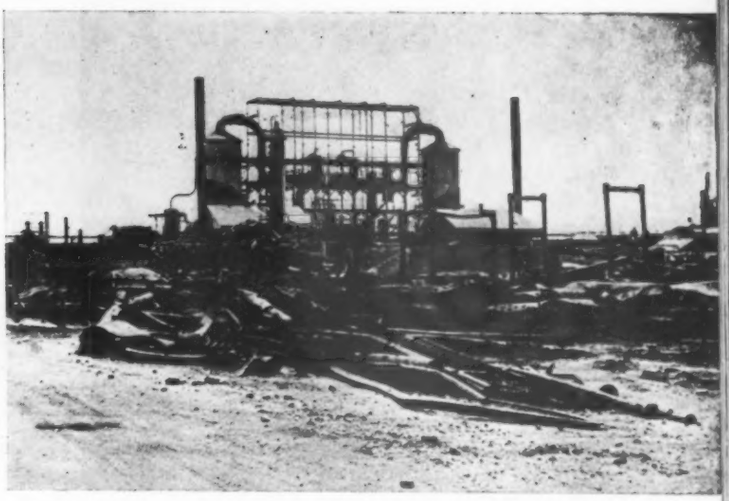
Publishes HF Alkylation Book

A new book, entitled Hydrofluoric Acid Alkylation, has just been published by Phillips Petroleum Company, Bartlesville, Okla. The volume is a compilation of a series of "Blue Books" which were distributed to a restricted group during the war, covering operating experience, pilot plant, research, and metallurgical investigations at various HF Alkylation units. With wartime secrecy requirements lifted, the book makes information concerning the HF Alkylation process available to all.

Numerous graphs and figures together with processing and laboratory facts are included with photographs and instructive flow diagrams illustrate the various chapters. The book is offered for sale through the Chemical Products Dept. of Phillips at $7.50 per copy.



View Along Palembang Avenue Showing Damage to Pipelines of the Nederlandsche Koloniale Petroleum Maatschappij Refinery.



Process Equipment at the Twice-Destroyed Refinery is Largely Junk and Reconstruction Will Cost $35-60 Millions.

RESTORATION WORK UNDER WAY AT PALEMBANG

Although Unsettlement in Sumatra Has Delayed Start of Reconstruction at Standard-Vacuum's Soengei Gerong Plant, Largest in the Far East, Assemblage of Materials and Personnel Is Going Forward in Furtherance of Plans for Early Opening and Subsequent Enlargement.

Since V-J Day the oil companies with producing and refining facilities in war devastated areas have been occupied with efforts to survey the extent of the damage suffered by their properties and with preparations for the reconstruction or replacement of plants that have been partially or wholly destroyed. In some areas progress in this direction has been delayed by continuing armed disturbances or by uncertainty as to future political conditions but it is known that in the aggregate the cost of rehabiliation will run to a thousand million dollar figure and will take several years to complete. The conditions affecting different properties vary greatly, of course, but the following article may be considered as typical of the sort of problems that must be faced, particularly in Japanese-occupied regions in restoring properties to normal production.—Editor.

BEFORE the war the Nederlandsche Koloniale Petroleum Maatschappij (NKPM), Netherlands East Indies subsidiary of the Standard-Vacuum Oil Company, supplied about one-third of the petroleum products consumed in the important Far Eastern markets. On the eve of the Japanese invasion of Sumatra, the producing equipment of the company and the Palembang Refinery in South Sumatra, together with the deepwater terminal at Tandjong Oeban, near Singapore, were all destroyed by the military forces of the Netherlands East Indies Government in accordance with a previously prepared denial program. However, the company is now engaged in carrying out plans to restore these facilities as rapidly as the political situation will permit, and as soon as materials can be supplied and experienced workmen can reach the scene. Upon completion of their plans, the Palembang Refinery again will be able to take its place as a supplier of petroleum products to the markets of the Far East, and in this manner contribute to the speedy recovery of these areas.

As early as October, 1945, slightly more than a month after V-J Day, Edw. N. Leibacher, general manager of NKPM, was enroute to the ruined remains of the refinery with a two-fold object—first, to institute a rehabilitation program for the hundreds of employees who formerly operated the refinery, and second, to measure the extent of damage and estimate the repair program necessary.

While the political situation has prevented the resumption of field work and even the sending of experts from Java to Sumatra for a detailed examination of the present condition of the properties, it has been possible, on several occasions, for one or two company men to visit the property for a few days. The information which they have obtained, as well as information from reports submitted by the Japanese who have been responsible, under Allied command, for guarding and protecting the refinery, has permitted some evaluation of present conditions and an approximate estimate of the cost of restoration.

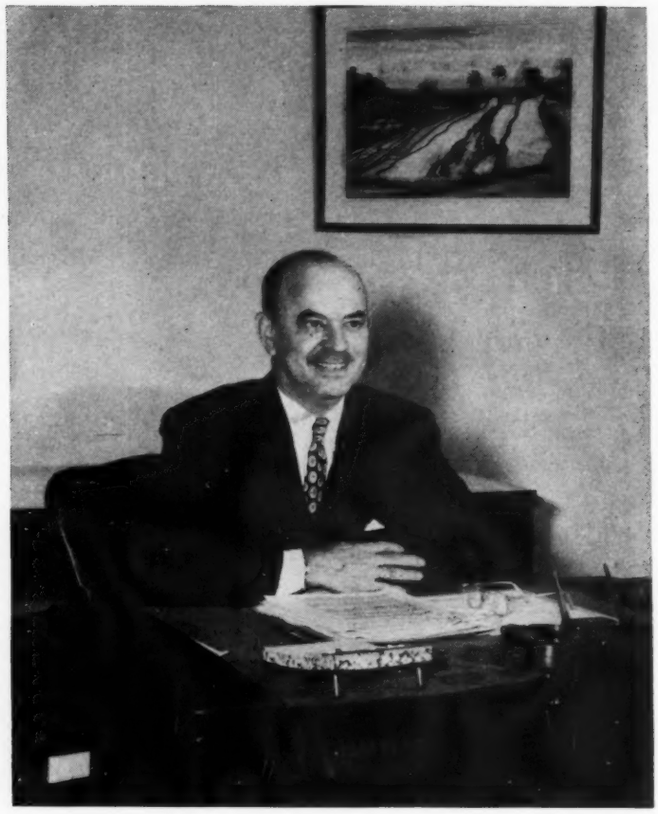
As a result of such preliminary surveys, Colonel L. W. Elliott, now vice-president and director of Standard-Vacuum, who preceded Mr. Leibacher as general manager of NKPM, announced that an expenditure of between $35,000,000 and $60,000,000 may be necessary for a complete rehabilitation and rebuilding program. However, initial expenditures will be limited to the repairs necessary to start limited production as soon as possible. A large part of the cost will be for labor and will be a direct and important contribution to the post-war welfare of the Hollanders, Indonesians and Chinese of Sumatra.

Tentative plans for the rehabilitation of the refinery have been prepared by Standard-Vacuum and NKPM engineers. On R- (for return, rehabilitation and repair) Day, the first groups of engineers and repair crews will move into the area and begin their work. But before R-Day can be set, materials must be ready and assembled and shipping provided. For this purpose the marine terminal at Tandjong Oeban and warehouse space in Batavia, Java, are being used as forward area "staging centers," and additional "rear echelon" groups and equipment are being formed in the United States. The first materials to go into Palembang on R-Day will be sanitary equipment, water-treating facilities, insect-control supplies, as well as a small group of engineers who will prepare the way for the inspection crews who will follow.

The inspection crews will make preliminary surveys of damage and estimate the work necessary to place the refinery back in operation. The "echelons" who follow them not only will make refinery repairs but, according to the plan, will build proper housing, arrange food storage, and institute a complete rehabilitation and training program for former employees.

Construction of the Palembang refinery, which is located at Soengei Gerong, about five miles down the Moesi River from Palembang, in

Col. L. W. Elliott, Vice President and Director, Standard-Vacuum Oil Co.



Edw. Liebacher, General Manager, Nederlandsche Koloniale Maatschappij.

southern Sumatra, was started in 1923. Innumerable difficulties were met and overcome before its completion in 1926. The refinery site was covered by dense jungle vegetation growing in what was quite literally swamp land. Almost 300 acres of the jungle were cleared and then millions of cubic yards of sand were pumped into the swamp from the adjacent river beds to raise the site above the water level. Most of the refinery equipment had to be supported on piling; approximately a million feet of piling have been driven since construction of the refinery began.

Before the war the refinery had a daily still-charging capacity of 45,000 barrels, and produced a full line of refined products, including aviation gasoline and wax. The Palembang wax plant was one of the largest, and the refinery's wax products were exported throughout the world.

Crude oil for the refinery came from the famous Palembang fields, where NKPM first began drilling in 1915. The crude is transported about 85 miles from the fields to the refinery, through two eight-inch and one six-inch pipelines.

In general, the construction of the refinery plant and the development of the producing area and the task of transporting crude from the wells to the refinery presented extraordinary problems. For example, the high paraffin content of the crude caused it to congeal in the pipes to such an extent that pumping became difficult, even in tropical temperatures. Wherever the pipes were shaded or under water the crude had a tendency to thicken to a point where pumping became impossible. To solve this problem some 40 miles of earthern dikes with trestles to support the lines across the swamp areas had to be built, and a wide path had to be cleared through the jungle so the sun could reach and warm the pipelines. The dikes were built by natives with hand tools.

In addition to the refinery, the producing fields and the pipelines, NKPM also operates a deep-water marine terminal at Tandjong Oeban, on the island of Bintan, about 30 miles southeast of Singapore. This terminal is necessary to load tankers fully, as a bar at the entrance of the Moesi River limits the drafts of ships going to or from the refinery to approximately 19 feet. Ocean-going tankers are loaded to about 60 percent capacity at Soengei Gerong and then proceed to Tandjong Oeban, where they are topped off. NKPM maintains a fleet of shallow-draft tankers to transport oil products to the terminal at Tandjong Oeban.

The NKPM installations and facilities on Sumatra were destroyed early on the morning of February 15, 1942, in accordance with plans made at the request of the Netherlands Indies Government. The landing of Japanese paratroopers on February 14 started what has been called "the greatest voluntary destruction in history." The oil supplies—and Palembang had 3,000,000 barrels of tank storage—were fired with pre-planted and fused incendiary bombs. Pipes were broken, valves and controls were smashed with heavy sledge hammers, records were burned. Distilling equipment was drained of oil and the furnaces lit, thus burning out the tubes and still bottoms. At the same time, out in the oil fields, workmen were dropping tools and pipe into the wells and plugging the holes with cement. Pumping stations and pipe lines were dynamited; even the telephone switchboards were demolished. At the marine terminal at Tandjong Oeban 1,000,000 barrels of tank storage were destroyed and pipes and valves were blown apart with explosive charges.

In spite of the almost total destruction the Japs eventually returned the refinery to fairly sizeable production until a series of Allied bombing attacks in January, 1945, again reduced operations to a mere trickle.

So it was to a twice-demolished refinery that Mr. Leibacher returned—a wreck which it is estimated will require a huge expenditure to rehabilitate completely. The spread of several millions in the estimate is caused by the fact that the Japs operated the refinery on a non-maintenance basis. Evidently they didn't expect their stay would be permanent, for they ran stills and

a complete inspection can be made for pitting and corrosion in vital parts it is impossible to say how much the final cost will be. Complete and detailed inspections will not be possible until shortly after R-Day.

At present NKPM's rehabilitation program is divided into three parts. At first the deep-water terminal at Tandjong Oeban will be repaired. In fact, repairs are being made now, just as fast as supplies and material can be shipped out. As soon as re-entry into the Palembang area is possible the refinery at Soengei Gerong will be partially reconstructed and placed in operation on a limited throughput basis. In this manner NKPM plans to get into production as soon as practical, for the Far East needs petroleum supplies immediately.

Reconstruction of the terminal at Tandjong Oeban is already well under way, for the company has free access to the property. An insight into the strange working of the Japanese mind is given by the additional destruction, or sabotage, which the Japs performed while they were there. Although much valuable and easily repaired equipment was left untouched, the invaders systematically removed lighting fixtures, domestic plumbing, window screens, hardware, and such things as door frames. But their removal was strangely incomplete and unorganized. For example, they would remove the switch button from an ordinary desk lamp but leave the lamp stand, frame and shade unharmed.

However, the damage is being repaired, and Tandjong Oeban is beginning to resemble the staging area and material supply dump which it is planned to be. The company has marine equipment back in operation including the DIDI, a passenger launch, and the TANDJONG OEBAN, a freighter. Living quarters and warehouses have been rebuilt and stores, food, fuel and the thousands of items which will be needed for R-Day and the following months are piling up.

The third part of the rehabilitation program depends entirely on the political and social situation in Sumatra. Just now the situation is one of unrest following the disorganization left by the war. When conditions become stabilized, the company expects to be able to expand its refining operations. Old refining equipment will be replaced, new storage facilities will be added. The plans for the future also include a modern catalytic cracking unit for the manufacture of high-quality aviation and motor gasoline in large quantities, for post-war developments in transportation in the Far East should require large supplies of first-grade fuel.

During the short visit which Mr. Leibacher was able to make to the refinery, he found that it was still guarded by Japanese, although no efforts were being made toward operation. At first the Allied authorities in charge were reluctant to permit him to travel through the plant without an armed guard, but after witnessing the manner in which he was received by former local employees who were doing such work as they could, he was permitted to explore freely.

He found that, with a minimum of expense and new equipment, the damaged facilities might be repaired so as to permit a balanced operation at an initial crude rate of 20,000 barrels per day. While this would be less than half the pre-war rate, it would represent a vital contribution to the rehabilitation of Far Eastern economy.

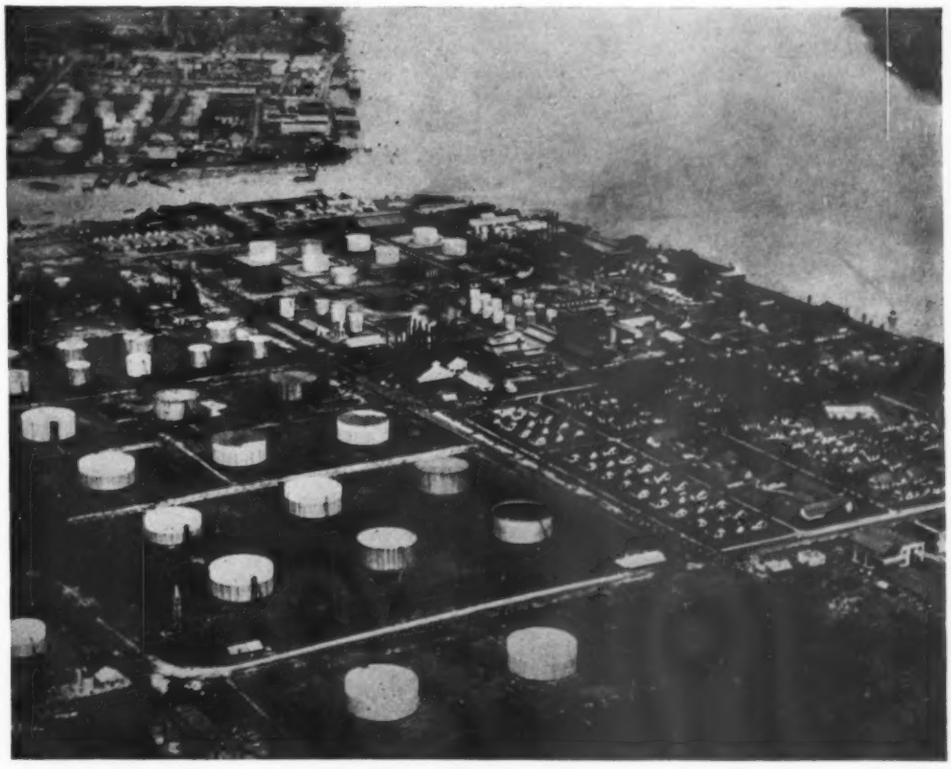
One of Mr. Ieibacher's main problems is the rehabilitation of employees. Before the war Standard-Vacuum employed approximately 10,000 persons in its East Indies oil operations. More than 9,000 of these were Indonesians and Chinese, while the rest were Hollanders and Americans. Many of the highly skilled employees were removed by the Japanese to labor or concentration camps, which, according to reports, were even worse than some of the notorious Philippine prisons. Many former employees died in these camps or were killed by the enemy during the invasion and the years that followed. In addition, many workers and their families moved from the Palembang region back into the jungles, or managed to reach other islands, and have not been able to return to their former homes. Mr. Leibacher is making every possible effort to locate them and furnish them with facilities for their return.

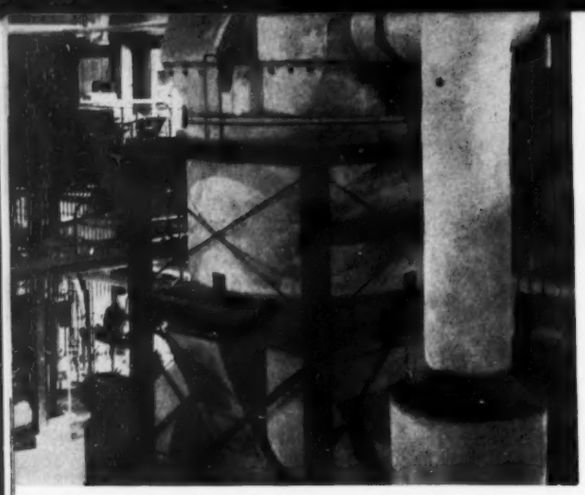
The company, which was formerly a leader in training the Indonesians for refinery work, plans to reinstate the same type of training schools as it had before the war. Not only will training be given to new employees, but refresher courses will be available for former workers who have been forced to be away from their old jobs since the destruction of the refinery.

In addition to new and refresher courses in the area other courses for key Holland personnel are being conducted by the company in the United States. These men are being brought up-to-date on wartime developments and improvements in refining and processing, and upon their return to the East Indies will be able to step back into the important positions which they held before the war.

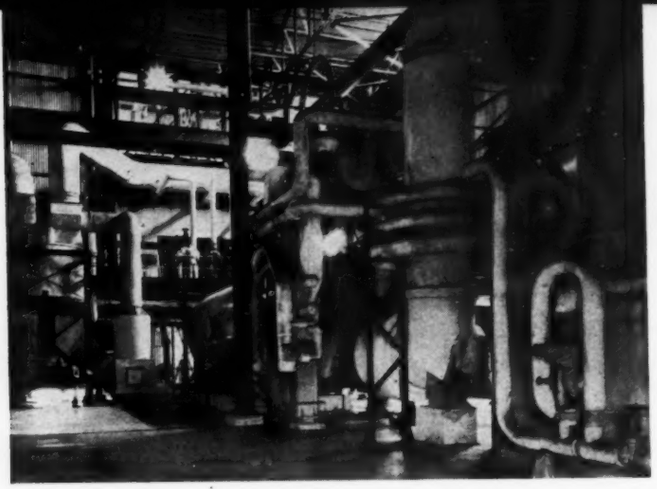
NKPM's primary idea at present is to get into operation as soon as possible. Its management feels that even a small output from the refinery will have a real value to the economy of a war-distressed people. While their long-range plans must await more stable conditions, they intend, by supplying vitally needed petroleum products and by furnishing profitable employment to as many nationals as they can, to do their part in contributing to the rehabilitation of the liberated countries and people of the East Indies.

Pre-War Aerial View of the Palembang Refinery at the Junction of the Moesi and Komering Rivers.





Raw natural gas is preheated to 660-750°F. before treatment with zinc oxide to remove sulphur compounds. At Lion Oil Company's Ozark plant.



Purified gas is mixed with steam and passed over a nickel catalyst in the primary reformer at 1290°F. to produce hydrogen.

OIL COMPANIES EXTEND OPERATIONS TO EMBRACE BROAD CHEMICAL FIELDS

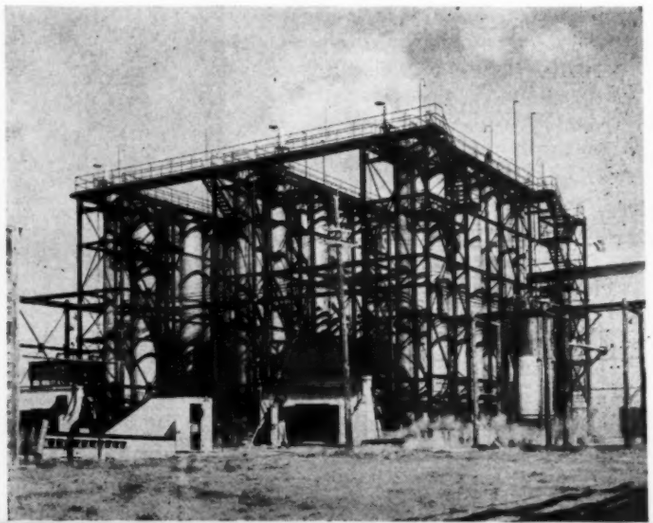
ONE of the notable trends in the oil industry which is becoming especially marked since the close of the war is the expansion of operations in chemical fields. This development is taking various forms among different companies. In one direction it includes the manufacture of chemical products from petroleum; in another it comprises chemicals in the making of which some petroleum by-product is employed; in the third instance chemical plants are owned individually or jointly with other interests as separate but related enterprises and not primarily as outlets for company products.

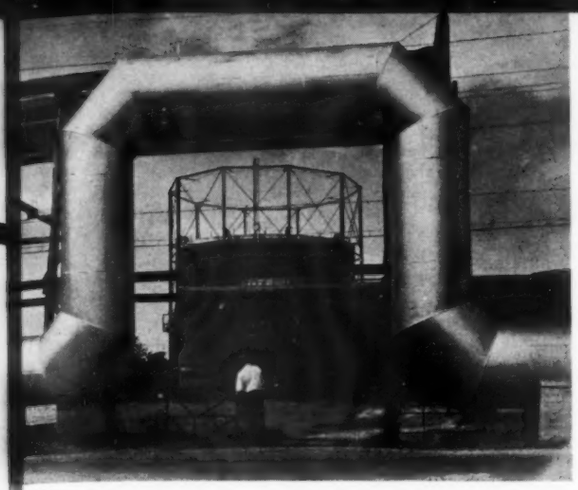
Most integrated oil companies have long engaged in the manufacture of certain chemical products such as insecticides, toilet preparations, paints and similar commodities and have maintained special departments in charge of these activities. More recently a number of companies have undertaken the large-scale production of industrial chemicals, setting up special divisions or affiliated companies to handle these operations. One of the pioneers in this field has been the Shell group which constructed a large nitrogen fixation plant at Pittsburg, California, in 1930. Principal products of this plant were anhydrous ammonia, aqua ammonia and ammonium sulphate, with carbon black, benzol and naphthalene as by-products. This was followed by a plant at Martinez, California, for the production of butyl alcohol, ethyl ketone, acetone and kindred products from refinery gases. In 1936 a third plant was built at Dominguez, California, to provide additional facilities for synthetic alcohols and ketones. Just prior to the war a plant was installed in connection with the Shell refinery at Houston, Texas, which was the first to engage in the commercial production of butadiene from petroleum. During the war this activity was greatly expanded by the addition of other plants which were operated for the account of the government. These installations, which produce a very wide range of chemicals, formerly were operated as the Chemical Division of Shell Union Oil Company but now form a separate corporation, Shell Chemical Company, which ranks among leading chemical concerns of the country. An example of joint ownership of a chemical enterprise is the Jefferson Chemical Company organized by The Texas Company and American Cyanamid Company to construct a plant at Port Nèches, Texas, to produce intermediate chemicals for the manufacture of synthetic rubber, plastics, textiles and other materials from petroleum and petroleum gases which will be supplied from The Texas Company's adjacent Port Arthur refinery. The section now under construction will comprise the first unit of what is ultimately to become a very large plant.

A striking departure from ordinary oil company activities was the acquisition by Lion Oil Company of El Dorado, Arkansas, of the nearby Ozark Ordnance Works built during the war by the United States government, and operated by Lion Chemical Company, a subsidiary of Lion Oil Company. The plant has been leased by the company for a term of five years with the privilege of two renewals for equal periods and is the first government-owned plant of its kind to be taken over for private operation. It has an annual capacity in excess of 165,000 tons of ammonium nitrate and 90,000 tons of anhydrous ammonia and is capable of supplying 11 percent of the nation's requirements of nitrogen. The contract provides for the immediate construction of a new unit to cost approximately $1,000,000 for the production of high-grade finished ammonium nitrate fertilizers. The original cost of the Ozark works which was one of eight ammonia plants built by the government for wartime use was $26,500,000 and, under Lion management it became one of the largest and

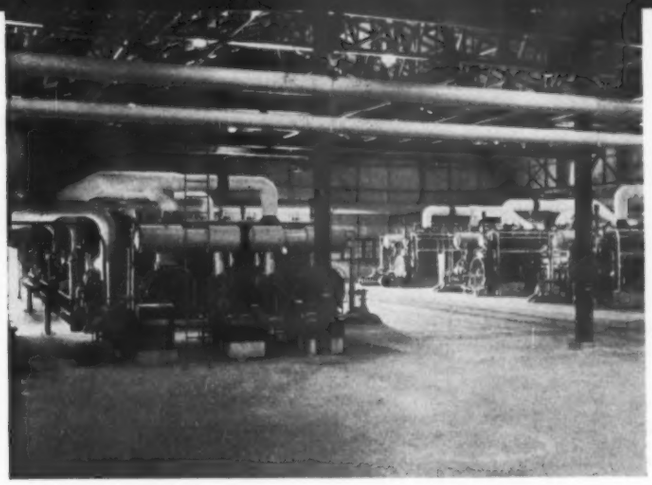
Finished ammonium nitrate is produced by neutralizing the nitric acid with ammonia and evaporating excess water.

Secondary oxidation of NO to NO_2 is accomplished in a series of absorption towers and nitric acid produced.





After secondary reforming at 1830°F. and introduction of nitrogen air the reaction gas is conveyed through this 54-inch line to the compressor building.



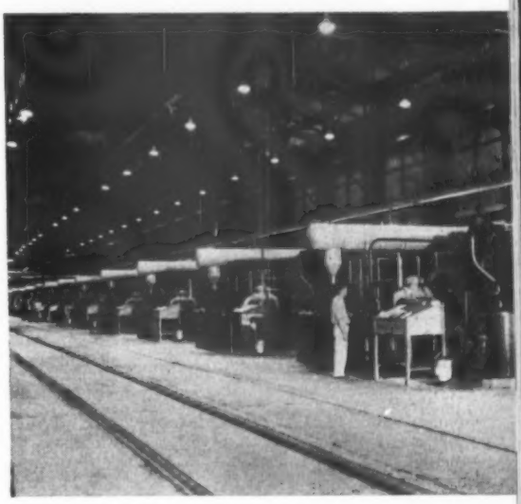
Reaction gas is purified by removal of carbon dioxide, carbon monoxide and oxygen. Pumps above supply water for CO_2 scrubbers.

most economical producers of ammonia and ammonium nitrate.

In the process employed at Ozark, only three raw materials are utilized, natural gas, air, and water. The catalytic synthesis process by which the transformation is accomplished is highly technical but, in simple terms, natural gas is reformed with steam to obtain hydrogen. Nitrogen is extracted from the atmosphere and added to the processed gas which then passes through a series of purification steps requiring various stages of compression. In the final step the processed gas contains only the proper proportions of one nitrogen to three hydrogen atoms united to form the completed NH_3, or ammonia.

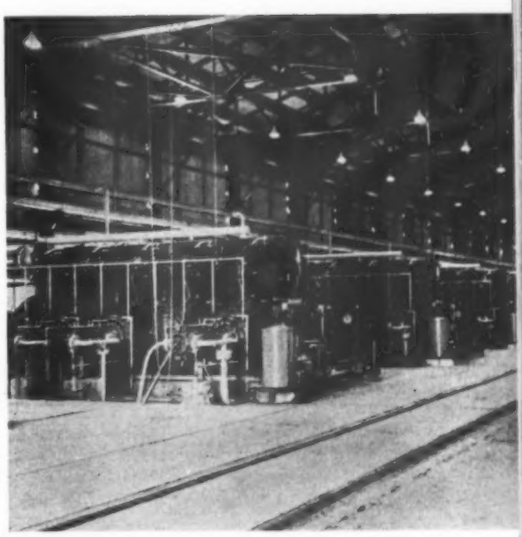
A quantity of ammonia is oxidized to form nitric acid which in turn is used with added ammonia to produce ammonium nitrate. This liquid is reduced to minute granular pellets and coated. These pellets are the finished ammonium nitrate fertilizer ready for use by the farmer. This process is conducted on a large scale at the Lion plant. The largest building houses 60,000 processed daily is greater than the domestic gas consumption of a city the size of Boston. Great quantities of water are required, yet economies in reconditioning and recirculating the water through five large redwood cooling towers greatly reduce the demands upon the underground reservoir. The amount of water circulated daily is comparable to the water consumption of Los Angeles. Due to efficiency of design, innate characteristics of the operation and employment of many automatic features, an exceptionally high degree of productivity is achieved with almost a ton and a half of finished product being produced per employee per day.

Compressors boost the partly purified Gas to 1800-1900 psi before the final purification in copper and caustic scrubbers. →



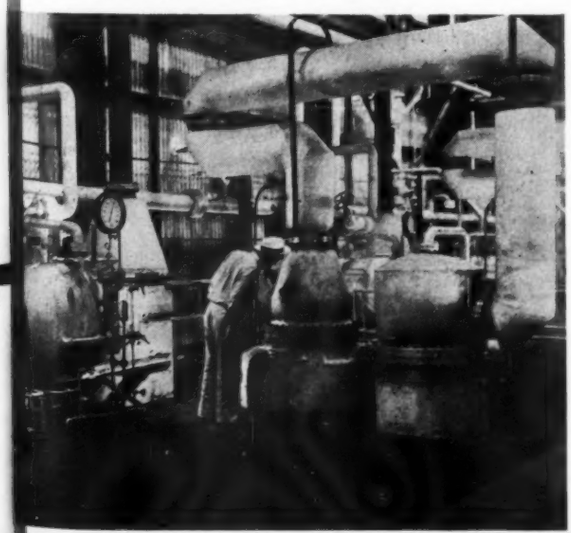
Lion's research organization has been studying for months other applications of organic chemistry and synthesis of gas hydrocarbons made possible by lease of the huge chemical plant. Some of the products contemplated in addition to those now being produced include dry ice, urea, formaldehyde, alcohol and plastics, all of growing importance in modern industry.

The demand for nitrogen fertilizer products, such as anhydrous ammonia and ammonium nitrate, in both liquid and solid form, cannot be met at the present time. National consumption of high-nitrogen-content fertilizers in 1945 exceeded two million tons. Over 60 percent of this amount was used in the twelve states which represent Lion's potential marketing area.

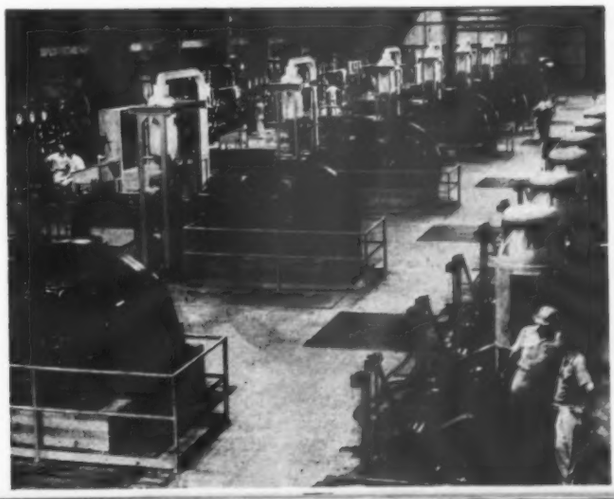


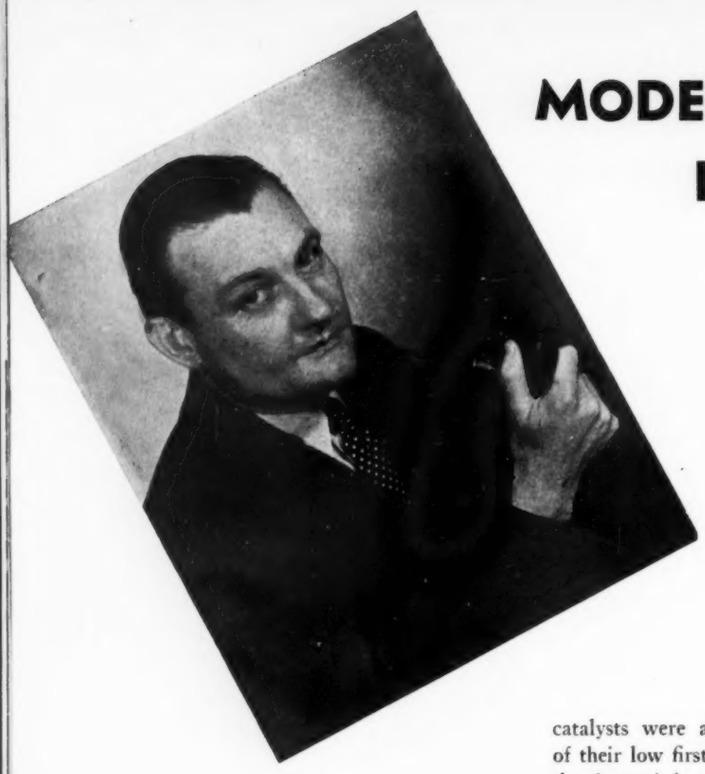
Purified gas is boosted to 5000 psi in 1000 hp. compressors before conversion to ammonia. →

View of gas synthesis building where hydrogen and nitrogen are combined with a catalyst to form ammonia.



Platinum gauze acts as a catalyst in the oxidation of ammonia at 1650°F. into nitrogen oxide. Worker is inspecting gauze through burner porthole.





MODERN CATALITIC PROCESSING IN SUMMARY

By SAMUEL S. ALLENDER*

DURING this period of conversion from war to peacetime economy, the refiner finds many catalytic processes available, from which he may choose those best suited to his processing needs for the production of improved motor fuels and related petroleum products. Detailed studies indicate catalytic cracking as the most adaptable process for the production of improved motor fuels, with catalytic polymerization as a valuable adjunct for the recovery of motor fuel constituents from the propylene and butylenes in the cracking operation. Although a number of other catalytic processes were in wide use during the war period, they are of immediate importance only to those refiners who have such units already erected in their plants and who can fit them bodily, or with some modification, into their postwar refining scheme. Indications are that, at present, they are of specific interest only under such conditions and will have no wide acceptance in the majority of refining plans now under consideration.

Most of the recent catalytic cracking plants built have been of the moving bed or fluid type. These latter, including the Thermofor unit, developed in the laboratories of Socony Vacuum, and the Fluid Catalytic cracking process, developed largely by the Standard Oil Development Company, have been proved in many commercial installations during the past five years. Subsequent modifications and improvements in design and operating technique, plus refinements in catalyst composition and manufacture, make these processes attractive to the refiner who is planning modernization of his existing facilities. Up to the time when demands for aviation gasoline rose to unprecedented heights, natural clay catalysts were almost universally used because of their low first cost and availability. However, the demand for aviation gasoline blending stock of low bromine number and for isoparaffins in the light hydrocarbon range, brought on the development of synthetic catalysts which are more selective in their action. The result has been that the refinery engineer has a selection of not only the process which will fit his plans, but also may select the type of catalysts which, on the basis of market considerations and operating costs, will give him the quality and quantity of products desired.

The development companies licensing available catalyst processes are currently publicising the results which can be obtained in various types of operation. Charge stock, charge pre-treatment, type of process and catalyst used, all have a profound effect on the character of the results obtained. Reference is made to the papers presented at the meetings of the American Petroleum Institute, the National Petroleum Association and the Western Petroleum Refiners Association for detailed accounts of the results which can be obtained by catalytic cracking using licensed processes.

In general, natural catalysts (activated clays) command consideration because of low first cost. although the gasoline yield is only intermediate and carbon formation is higher than that obtained with synthetic types. Synthetic silica-alumina catalysts give the highest octane rating gasoline and would be used where this factor is the primary consideration, while synthetic silica-magnesia catalysts produce the highest yield of gasoline with some sacrifice in octane rating.

Granular natural catalysts were first used in the older fixed bed catalytic cracking units, being rapidly supplanted by pelleted types because of the higher mechanical strength, less attrition, and more uniform pressure drop distribution throughout the catalyst bed. Natural catalysts were also employed in moving bed operations during the early stages but the use of bead catalysts was broadly accepted by the plants using the TCC process for manufacturing aviation gasoline blending stock during the war. The bead catalyst gives increased octane quality and production and is less affected by sulphur and nitrogen in the charge. These hard glassy beads have proved very satisfactory also because of their high mechanical strength and remarkable resistance to attrition. Their activity characteristics have prompted the manufacturers to adapt them for uses other than catalyst cracking and modifications are now being offered for dehydration.

The powdered catalysts, used in the fluid type units, were ground to size specifications (approximately through 100 mesh) so that the resultant powder moved through the units in a manner analogous with fluids; hence the name of the process. These ground particles were not uniform in size and there have been indications that the angular surfaces caused by grinding favored attrition in use with the result that special secondary recovery methods had to be incorporated in fluid catalytic cracking plant design to prevent the waste of large quantities of catalyst unaffected by the cyclones used as primary recovery units.

A significant advance in fluid catalyst manufacturing technique has been the development of the microspherical catalysts used in the MS-type catalytic cracking unit, developed by Universal Oil Products Company. The uniformity of particle size and the reduction in attrition losses, due to the smooth surface of this catalyst, has resulted in the elimination of the expensive secondary recovery systems in catalytic cracking plans using this material.

Development work is currently being carried on toward elimination of some of the less desirable features of natural catalysts and also in the field of synthetic catalyst preparation to obtain more selective action and lower carbon formation.

The catalytic polymerization of olefinic gases produced by cracking was the first process of this kind to be generally accepted by the refining

* Samuel S. Allender, Manager of Technical Sales, Flourides, for Harshaw Chemical Co., joined Universal Oil Products Co. as a supervising engineer in 1937 after several years as chemist and gasoline plant superintendent in the Mid-Continent. He was technical assistant to the president of UOP from 1939 until 1943 when he left to supervise construction of the Premier Oil Refining Co. aviation gasoline plant. He joined Harshaw Chemical in 1945.

industry. Sulphuric acid and phosphoric acid mixed with kieselghur were the two catalysts initially used and they have maintained their importance in this field. Shell was the chief proponent of the use of sulphuric acid and used this type of process in the United States and abroad for both non-selective and selective polymerization. The use of a liquid catalyst has certain disadvantages and the extruded phosphoric acid-kieselghur catalyst, which could be used in a fixed bed operation, has been adopted in the largest number of installations. When this process was first brought into commercial operation its use was considered justifiable only in installations where a large volume of gases could be treated. Universal Oil Products first showed that polymerization could be adapted and used successfully by even the smallest refiner having cracking facilities. Units processing as low as 200,000 cubic feet of refinery gas per day have been installed and operated to advantage.

The isomerization of normal butanes to isobutane was carried on by a large number of refiners during the war to produce raw material for alkylation and some installations isomerizing normal pentane to iso-pentane were made to increase the supply of that material.

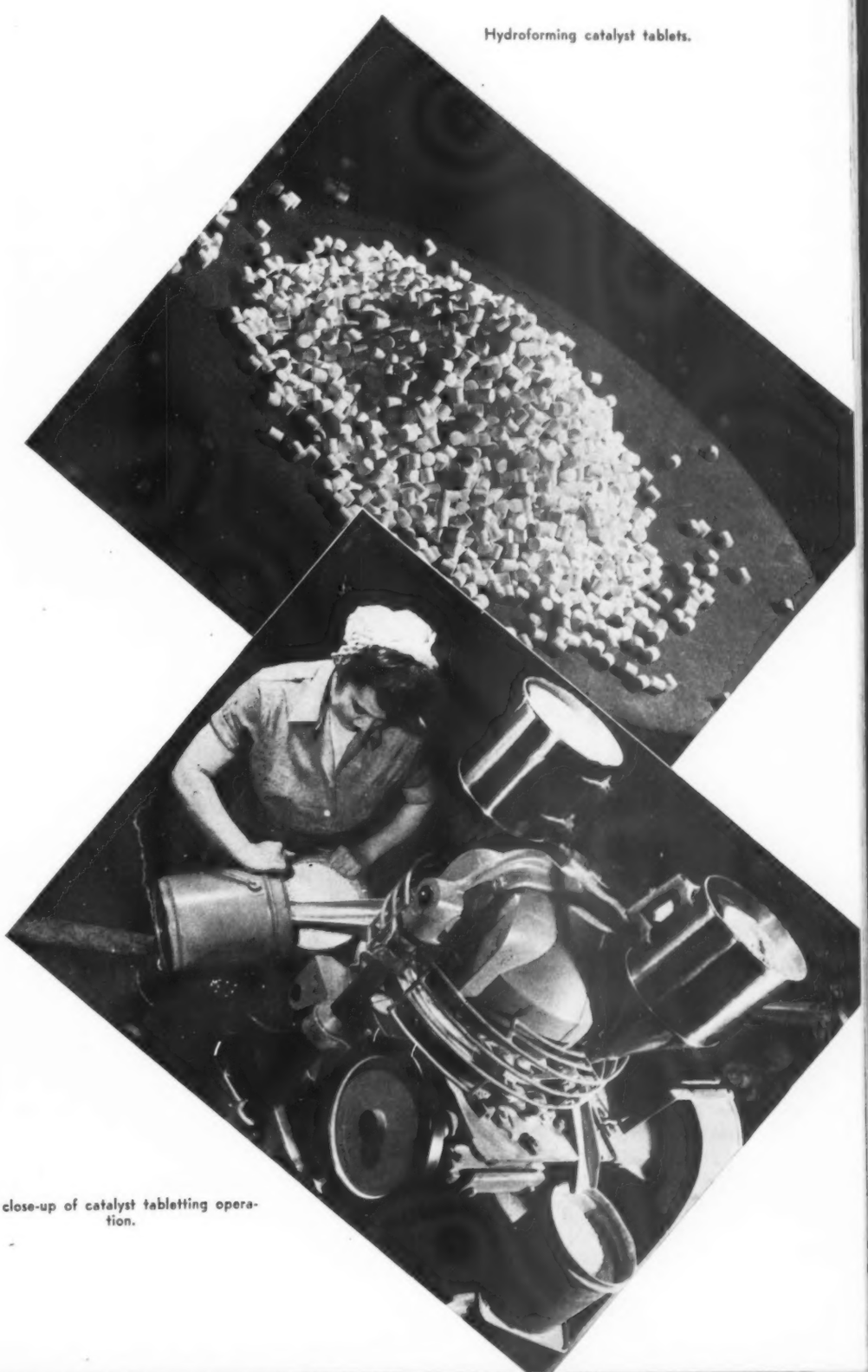
Isomerization of heavier hydrocarbons such as hexane and heptane has not been carried out on a large scale. There is a definite future for this type of operation and isomerization of these heavier hydrocarbons may be attractive in specific instances in refinery operations and may become of interest to natural gasoline manufacturers to raise the octane rating of their product in line with the rising level of octane rating in motor gasolines.

Aluminum chloride was used in all of the isomerization processes in connection with hydrogen chloride as a catalyst promoter. This material is plentiful and inexpensive and has proved itself as an efficient catalyst.

The production of commercial iso-octane before the war was carried out commercially, first by selective polymerization of butylenes to iso-octenes and subsequent hydrogenation to iso-octane. Just before the war alkylation of isobutane with butylenes using sulphuric acid as a catalyst came into prominence for the production of this material. The use of sulphuric acid as an alkylation catalyst was general among refiners who installed private facilities to help meet the increased need for aviation alkylate. In aviation gasoline plants financed by the government, however, anhydrous hydro-fluoric acid was almost universally used as an alkylation catalyst. This was due to the ease with which this catalyst could be regenerated for reuse and to the fact that refrigeration equipment did not have to be installed for removing the heat of reaction. HF alkylation proceeds at temperatures high enough to allow ordinary refinery cooling water to be used as a heat removing medium.

Although HF alkylation entered the field of commercial operation with very little established background beyond the pilot plant stage, it was definitely proved to be an efficient and economical catalyst during the war. Experience gained during this period has shown that units may now be built with a catalyst consumption of about 0.6 pound of acid per barrel of alkylate produced. One of the plants erected for the wartime production of alkylate using anhydrous hydrofluoric acid is now operating at somewhat below the capacity of the unit and consuming less than 0.4 pound of acid per barrel of alkylate produced. The Hydroforming Process, developed by M. W. Kellogg Company, Standard Oil Company (Indiana) and Standard Oil Development Company, is essentially a reforming process using catalysts for treatment of heavy naphthas, from topping or cracking operations, in the presence of hydrogen gas. Since the products of the hydroforming operation are highly aromatic, use was made of this process in providing the major quantity of toluene used during the war in the manufacture of trinitro-toluene. In order to provide the maximum quantity of toluene in the product, selected raw materials were used, largely methycyclohexane, obtained from selected crude petroleum stocks by precise fractionation.

Hydroforming catalyst tablets.



A close-up of catalyst tabletting operation.

Bird's eye view of the synthetic bead catalyst plant of the Socony-Vacuum Oil Company, Inc.

The operation is carried on in fixed bed reactors, the crude charge going to the reactors in an atmosphere of recycle gas rich in hydrogen. The catalyst is a synthetic mixture of alumina and molybdenum, used in either a large granular, pelleted, or extruded form, although natural metallic oxide catalysts may be employed.

The method of preparation of these catalysts and the form in which they are used has considerable effect on the quantity and quality of the products obtained. Much research and development work has been done on preparations of synthetic catalysts with the view of adapting the hydroforming operations to peacetime petroleum processing. Although the hydroforming process is an excellent method for increasing the octane number of heavy, low-grade naphthas and for this purpose may be utilized by refiners who have these existing facilities in their plants, the same results can be obtained by catalytic cracking. Therefore, the field of use for the hydroforming process is not as wide as that for the various catalytic cracking methods now available.

Dehydrogenation assumed some importance in the wartime economy. The production of butylenes from cracking operations was not sufficient to furnish both alkylation and synthetic rubber operations with a sufficient amount of unsaturated materials. Several units were installed for the dehydrogenation of butane to butlylenes for this purpose. Two of them, operated by Great Southern Corporation and Premier Oil Refining Company of Texas, were based on the improved designed data obtained from the first large scale commercial butane dehydrogenation unit erected during 1939 in England. These plants were both used for the production of butylenes going to alkylation units. Butane dehydrogenation for the production of butadiene for synthetic rubber was also used by Phillips Petroleum Company at Borger, Texas.

Chrome-alumina dehydrogenation catalyst, in the from of ⅛-inch pellets, was employed in a fixed bed operation, the catalyst, being distibuted in small reactor tubes operated in banks as individual reactors. Considerable development work has been carried on in butane dehydrogenation, using the fluid catalyst technique. However, there are certain difficulties which have not, at yet, been overcome in raising the operating efficiency to an economical level.

Due to the high operating cost and high initial investment, butane dehydrogenation does not appear economically feasible for peacetime butylene production, where butylenes are to be subsequently processed for polymerization or alkylation purposes. Small units may be indicated for the production of raw materials for chemical purposes. Propane dehydrogenation has also been studied and is a commercial possibility.

Dehydrogenation of butylenes to butadiene, while possible with the chrome-alumina catalyst used in butane dehydrogenation, was carried on during the war by a process developed by the Standard Oil Development Company. This process used a catalyst which was not poisoned

Workman inspects the flow of hydrogel from the nozzle onto the fluted distributing cone.

in the presence of water vapor, hence the process could be carried on at low partial pressures of butylene by introduction of superheated steam, thus avoiding the use of vacuum equipment to carry on the process at the low pressures required to keep down carbon and undesirable by-product formation.

Prior to 1940, hydrogenation in the United States was limited and most units used the so-called high pressure technique. Some installations of low pressure hydrogenation had been made for the purpose of hydrogenating iso-octenes produced from selective polymerization to form iso-octane for aviation gasoline blending. The use of selective polymerization with subsequent low pressure hydrogenation was restricted to those refining operations of sufficient volume to provide large quantities of butylenes for this process.

The demand for iso-octane rose so rapidly during the war that emergency measures had to be taken to satisfy the requirements. Much ingenuity was used and it was found that with a minimum installation of equipment, many of the existing non-selective polymerization units, using phosphoric acid catalysts, could be operated to form a crude iso-octene or codimer which, on hydrogenation, would produce an iso-octane of suitable quality for aviation gasoline blending. Many of these small polymerization units were revamped and produced codimer sufficient to occupy the capacity of existing high pressure hydrogenation units which transformed them into hydrocodimer.

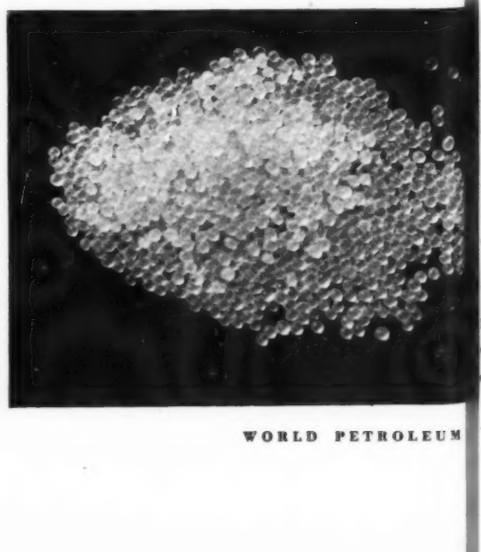
Iso-propyl benzene (cumene) was found to be a valuable aviation gasoline component and production of this material could also be made in certain existing catalytic polymerization units using phosphoric acid as a catalyst. Benzene was charged to the reactors in admixture with propylene; the alkylation reaction proceeded in the presence of the phosphoric acid catalyst and cumene was produced as a finished product. This same catalyst was also used in the production of ethyl benzene which, on dehydrogenation, yields styrene valuable in the manufacture of butadiene-styrene synthetic rubber.

Codimer, cumene and ethyl benzene were essentially was materials and have no large quantity place in present peacetime petroleum refinery processing.

Much interest has been shown, and a vast amount of work is currently being carried on, to perfect catalysts and catalytic techniques for petroleum processing. At the present, catalytic cracking, using one or another of the present established processes, appears to be the immediate answer for high quality motor gasoline. Catalytic polymerization has proved its worth and has been accepted almost universally.

Each refiner will find use for one or more of the developed processes listed above. The experience gained during the war plus the vast amount of research and development work currently being carried on, will keep the techniques of catalytic processing abreast of the needs for fuel to meet new engine requirements.

The finished synthetic bead catalyst.



CATALITIC CRACKING FOR THE SMALL REFINERY

By DR. O. W. WILLCOX
Technical Editor

THE shape of things in the new era into which the oil refining industry is now about to enter has become fairly evident in a number of directions.

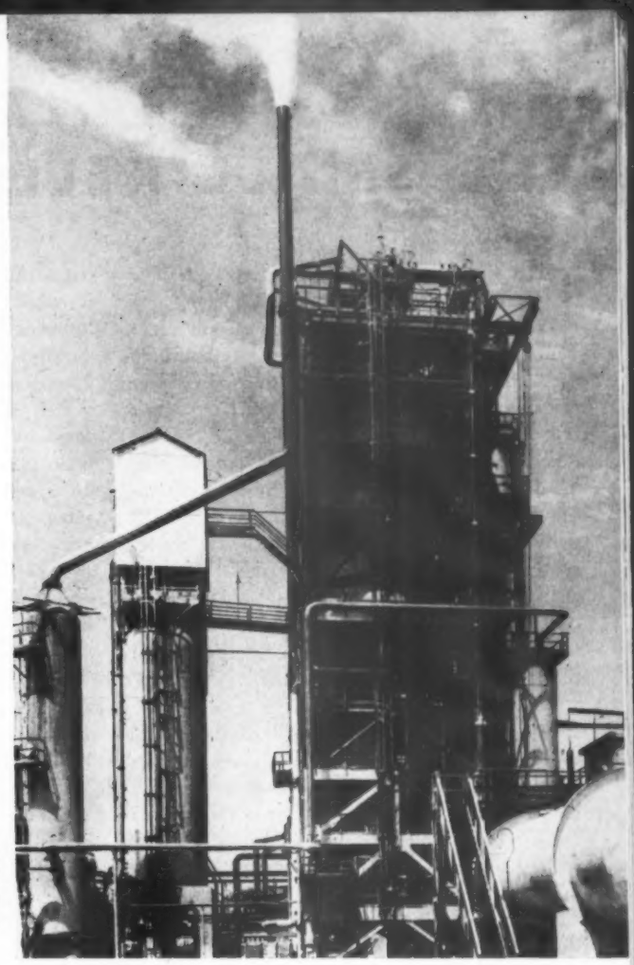
Instead of a sharp dip in the curves of petroleum demand and supply which was generally expected with the close of the war, it turns out that the drop in consumption has been much less than the estimates. The statisticians now figure that the demand for oil in 1946 will be 10 or more percent above what it was in the fall of last year. There has been a heavy demand for fuel oils, and in the first quarter of 1946 the demand for gasoline was 15 percent greater than the estimates. Some moderate dips are expected, but once the automobile industry returns to normalcy the demand for gasoline will soar.

The foregoing is intended to point up the prospect of an expanding market that will be open to refiners who can take advantage of it, meaning those refiners who can meet the new quality specifications for motor gasoline that are coming in with the new era.

The new cars, when they get here, will be designed for gasoline of 80 octane number for housebrand grade and 85 octane number for the premium grade. At the present moment there is a shortage of lead for the manufacture of TEL which is serious enough to have prompted an earnest suggestion that the octane rating of housebrand gasoline be cut by 1.5 points—from 80 to 78.5. The shortage of lead may be more or less temporary, but a reduction of octane requirement to 78.5 still leaves the quality specification much higher than formerly. In any case, the producers of motor fuel must now key their refinery operations to the manufacture of a higher grade of gasoline than ever before.

There are a number of refineries, including those of many of the major oil companies, to whom the upward revision of motor fuel specifications presents no problem of consequence. These companies, at the end of World War II, found themselves in possession of large units, for alkylation and for catalytic cracking, which were erected, under governmental direction and in some instances with federal financial assistance, to meet the urgent military demand for 100-octane aviation fuel.

With the passing of the military crisis these major companies are now able to turn this excellent equipment to the far less exacting task of producing gasolines of 80 to 85 octane.



The World's Smallest Catalytic Cracking Unit Now in Service is the 2,600-Barrel Fluid Cracker Designed for Frontier Refining Company, Cheyenne, Wyo., by Universal Oil Products Company and Built During the War.

On the other side of the picture are the great majority of refiners who came through the war without catalytic cracking equipment. Military requirements demanded 100-octane gasoline in enormous quantities, which could best be furnished by single or combined units that could crack from 20,000 to 70,000 and more barrels a day. Consequently little attention was paid to the adaptation of processes and equipment to smaller plants.

This wartime development of catalytic cracking created a serious problem for the small refiner, who may be defined as the operator of an oil refinery with a capacity of 10,000 bbl. a day or less. This definition takes in more than 70 percent of the 450 oil refineries in the United States. These plants, operating by the thermal cracking process, are not in a position to produce 80 or 85 octane number motor fuel except at a cost that is practically prohibitive. The best they can do is to use selective fractionation of straight run gasoline to get a maximum of high octane constituents, and to practice polymerization and reforming of thermally cracked products, which still leaves them with small yields of high specification products and large volumes of lower grades and low priced goods. The upshot is that the small refiner must now, somehow, change his base from thermal to catalytic cracking or go down before the competition of the more efficiently equipped producers.

To meet this situation engineering firms which built and put into successful operation the huge plants that supplied the Allied forces with 100-octane fuel during the past year have directed their efforts to altering the design and scaling down the dimensions of their units to the point where they are suited to the needs, and are within the financial reach of small refiners.

The following accounts of systems designed for putting catalytic cracking processes within the reach of small refineries has been received from the designers and builders of such equipment. The descriptions and illustrations of these systems are intended to show how the transformation from the large to the small units has been effected, without sacrifice of the fundamentals of technological efficiency while preserving a maximum of earning power. In each case the builders have supplied estimates showing what their respective units may be expected to accomplish under assumed conditions that may be regarded as typical.

Such estimates are necessarily of a generalized nature. Two refineries will hardly ever encounter identical conditions, and it is not surprising that the estimates here given show differences of a cent or more in the overall cost of a gallon of gasoline. The refiner who analyzes his own particular case may find that none of the estimates square exactly with his calculations. This will be particularly true where it is found that more or less of the existing thermal equipment can be integrated with the new catalytic equipment and thus reduce to some extent the overall cost of the modernized plant.

THE SMALL KELLOGG FLUID CAT-CRACKER

THE small fluid catalytic cracking units now being offered by the Kellogg Company represent a marked simplification when compared with the huge fluid units that were built during the war, when it was imperative to produce large amounts of aviation gasoline quickly. To attain this object these units were over-designed. Later experience has pointed the way to a number of improvements and simplifications in the mechanical arrangements and the details of processing without in any way sacrificing the basic fundamentals of catalytic cracking by the fluid process. One of these improvements has led to the elimination of mechanical conveyors, which has made it possible to arrange both the reactor and the regenerator at the same level.

A typical flow sheet of the small Kellogg fluid cat cracker is shown by an accompanying diagram. This diagram is for a 4000 barrel per day fluid cat-cracker which is now being constructed for a refinery having a crude running capacity of 10,000 barrels per day. Of interest is the fact that the main structure is compact, occupying an area of only 1650 square feet, which is about half the area of an average city lot.

Elevation, too, has been radically reduced. This latest design features reactor, regenerator, and precipitator all supported at the same elevation —only 69 feet above the ground. This latter improvement required a careful re-design of the entire unit in order to harmonize the variables of pressure, temperature, velocity, etc., into a balanced whole requiring minimum use of utilities.

The unit in general also includes a number of other changes which are expected to result in reduced investment, operating and maintenance costs, and continuous runs of better than a calendar year. For instance, all vessels except the regenerator can be shop-fabricated. An improved piping design and special "sizing" of the major catalyst lines have eliminated the necessity for internally lined piping and have reduced erosion to a minimum. Heat savings have also been effected through a re-routing of piping; gas velocities have been reduced; precipitator equipment has been improved; expansion and rotation joints have been eliminated.

The essentials of the fluid catalytic cracking process are more or less generally understood, but a brief restatement may be in order. The catalyst is a finely powdered substance, heavier than air and flows practically like a liquid. The oil feed, after passing the pump and the preheat furnace, is incorporated with catalyst flowing down the side leg of the regenerator. The catalyst is so hot that the oil charge is vaporized; the mixture of vapor and powdered catalyst rises into the reactor, where the cracking reaction takes place. The vaporous cracked products pass through a cyclone into the fractionator; the heavier spent catalyst dust rises in the reactor only to a certain level, and back-flows through the outside stripper and down to a pipe through which it is blown by a current of air into the regenerator, where the carbon is burned off it. Here again the regenerated catalyst rises only to a certain level, from whence it back-flows down the side leg to join incoming oil and repeat the cycle. The flue gases pass out through a cyclone in the top to a Cottrell precipitator; on the way the gases give up their heat to a steam boiler.

These units are designed with the view to handling heavy oil fractions—the heavier the better—because research and experience show that as the gas oil charge becomes heavier, the advantage of catalytic over thermal cracking increases.

As regards degree of conversion the design of the unit provides for considerable flexibility to follow the market in octane requirements. At the moment, the most economic conversion level is between 45 and 55 percent; a higher conversion results in more coke and gas without substantially increasing gasoline yield. If a higher quality of gasoline is required, or if there is a reduction in the amount of available charge, recycling may be used to attain a higher conversion level on the fresh feed.

The small Kellogg cat-cracker has also been designed so that both the reactor and regenerator operate at comparatively low pressure. Operation at a higher pressure would admit a further reduction of the dimensions of the unit and hence of the cost, but the consumption of power and other utilities, increased coke yields and reduction of the octane number of gasoline, would wipe out the savings in initial cost.

These units have built-in versatility to handle any type of charging stock and thus provide a proper balance between external and internal facilities. The refiner installing one of these units is advised to make provision for a feed pre-heat furnace, so that operation at the optimum conversion level will always be possible, regardless of kind of feed. As regards type of catalyst, natural or synthetic, suitable for use on the fluid principle, the design of the unit admits of operating with any of them.

An important point is provision of means for complete recovery of the catalytically cracked products, that is, to prevent entrained and absorbed hydrocarbons from being carried into the regenerator where they would be lost through combustion. The latest design of the Kellogg cat-cracker provides improved stripping with less deactivation of the catalyst by withdrawing the spent catalyst to an outside stripper, where it is brought into counter-current contact with the stripping medium. Equally important is prevention of waste of catalyst in the flue gas. The newest design provides a single stage cyclone in the reactor and regenerator, and an electrical precipitator of an improved type for treating the flue gases.

Another important point in the design of this unit is provision for complete removal of catalyst from the product stream. A scrubbing system in the bottom of the fractionator is provided to recover entrained catalyst and thereby prevent fouling of the equipment and contamination of reaction products. This system has performed most excellently.

The designers have gone to the limit in the elimination of the Numan equation from the operation of these small units, which in this respect are on a par with the larger ones. The vital factors of stream flows, temperatures and pressures, all of which have a decided influence on cost of operation, yield and quality of product, as well as the useful life of the equipment, have been put under the control of automatic instruments.

The provision of these automatic controls, plus the simplicity and ruggedness of details of construction, have enabled these units to make an astonishing record of long runs, so that downtime is at a minimum and earning power at a maximum. The present 90% stream efficiencies of Kellogg fluid units and runs of longer than a calendar year are expected to be even greater in the future.

According to the designers, the small Kellogg fluid units are in no sense to be regarded as abbreviated or abridged reproductions of the larger units. Whether designed for capacities of 30,000 barrels per day, such as a major oil company might order, or for 1700, 2250 or 4000 barrels, such as are now being designed and built for small installations, the fundamentals of the fluid process are integrally preserved in all.

To show what the refiner may expect from these units the Kellogg Company has made factual analyses of two typical small installations. One of these is for a refinery processing only 4500 barrels of crude per day. The estimates show that such a unit may expect to show a net operating credit of about $700,000 per year before depreciation and taxes. The other estimate, based on an average daily run of 9500 barrels a day, shows a similar annual credit of about $1,200,000. These conditions will vary from place to place and from time to time, so each case must be treated as a separate problem.

Table I

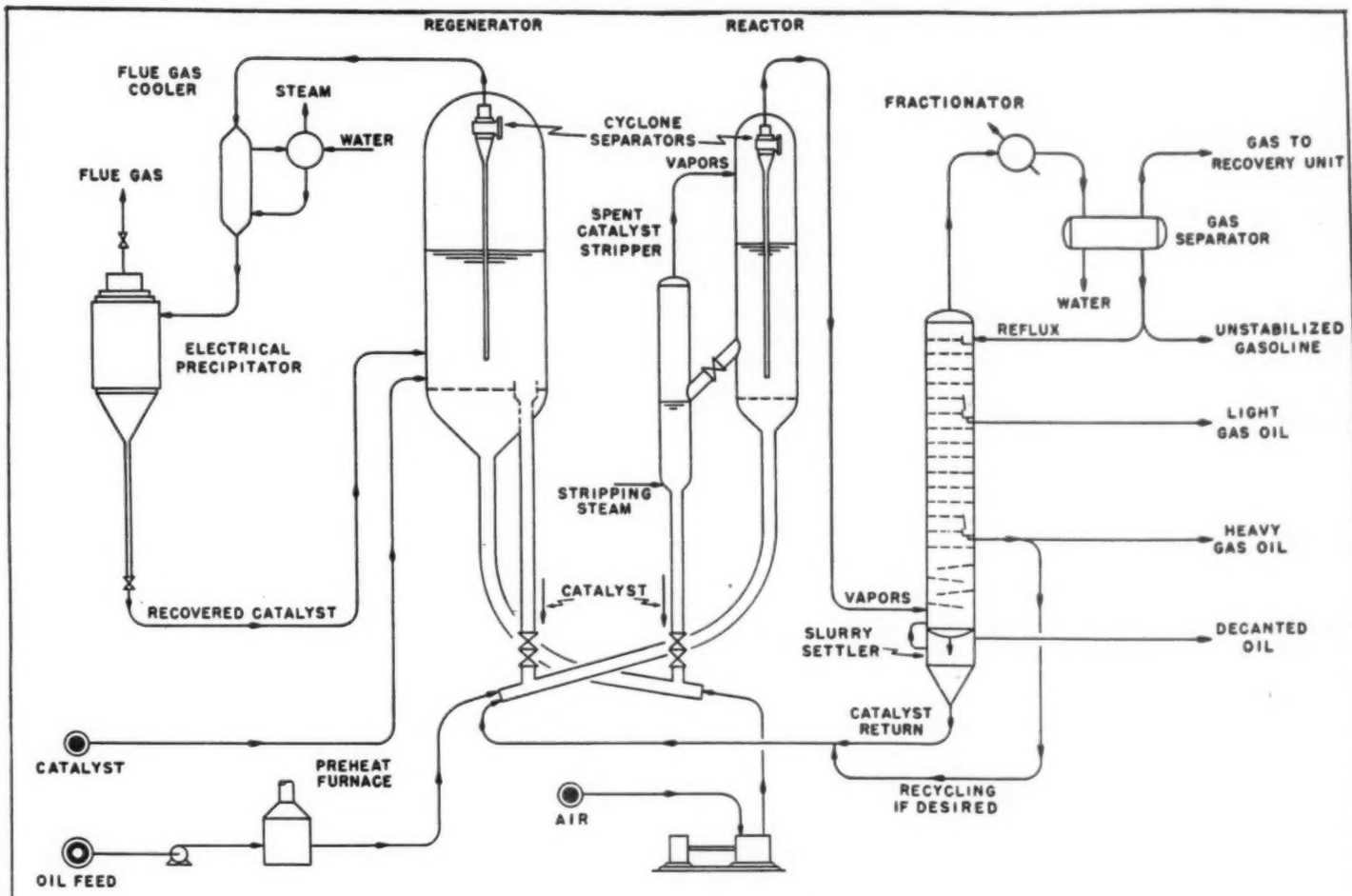
Economics of a 4500 BPCD Kellogg Fluid Cat-Cracker Operating on 39° API Mixed Base Crude

Credits	Unit Price ¢/Gal.	BPCD	Percent	Dollars/CD
Motor Gasoline (80 CFR-M)	6.75	3,105	69	$ 8,803
Straight Run Distillates	5.25	540	12	1,191
Heavy Fuel Oil	2.75	495	11	572
Gas (Fuel Oil Equivalent)	2.75	405	9	468
Total Credits		4,545	101	$11,034
Debits				
Crude Oil	$1.50 bbl.	4,500	100	$ 6,750
Direct Operating Costs:				
(a) Topping, Thermal Operations, etc				555
(b) Fluid Cat-Cracker & Gas Recovery				935
(c) Catalytic Polymerization				140
(d) Leading (0.7 cc TEL per gallon)				170
(e) Misc. Plant Expense incl. Royalties				420
(f) Taxes and Insurance, etc.				160
Total Debits				$ 9,130
Net Refining Operating Credit per Year Before Depreciation and Taxes				$694,960
Motor Gasoline Manufacturing Cost Before Depreciation Charges				5.29 cents per gallon

Table II

Economics of a 9500 BPCD Kellogg Fluid Cat-Cracker Operating on 36°API Paraffinic Crude

Credits	Unit Price ¢/Gal.	BPCD	Percent	Dollars/CD
Premium Gasoline (85 CFR-M)	7.5	1,045	11	$ 3,292
Housebrand Gaso. (80 CFR-M)	6.5	5,985	63	16,339
Total Gasoline		7,030	74	19,631
Heavy Fuel Oil	2.4	1,805	19	1,819
Gas (Fuel Oil Equivalent	2.4	855	9	862
Total Credits		9,690	102	$22,312
Debits				
Crude Oil	$1.55 bbl.	9,500		$14,725
Direct Operating Costs:				
(a) Topping, Thermal Operations, Etc.				1,150
(b) Fluid Cat-Cracker & Gas Recovery				1,100
(c) Catalytic Polymerization				240
(d) Leading (1.6 cc/gal. in Housebrand)				875
(e) Misc. Plant Expense incl. Royalties				780
(f) Taxes and Insurance, etc				250
Total Debits				$19,120
Net Refining Operating Credit per Year Before Depreciation and Taxes				$1,165,000
Total Gasoline Manufacturing Cost Before Depreciation Charges				5.57 cents per gallon



DIAGRAMMATIC FLOWSHEET OF KELLOGG FLUID CATALYTIC CRACKING UNIT

THE SMALL THERMOFOR CAT-CRACKER

THE Houdry Process Corporation made the first successful attempt to apply catalytic cracking in its modern form to the refining of petroleum. The first Houdry cat-crackers were of the fixed-bed type. In this type the catalyst is sealed in a large vessel and hot oil vapors are passed through until the efficiency of the cracking reaction falls off, due to the accumulation of carbon on the grains of catalyst. Then air is introduced to burn off the carbon; the efficiency of the carbon is restored, and the cycle is repeated.

The original fixed-bed installations are still giving satisfactory results but the design of new installations of the Houdry process has been shifted in the direction of a moving bed which makes it possible to carry on the catalytic process continuously. Instead of shutting down the apparatus for regeneration the spent catalyst that has made one passage through the reactor is removed to another vessel for regeneration and then returned to the reactor.

This form of the Houdry process has been named Thermofor Catalytic Cracking (TCC). The essentials of the cracking section of a TCC installation are shown in the diagram.

The main components of the catalytic section of a TCC unit consist of the reactor where oil vapors are contacted with hot catalyst, the kiln where the resulting carbonaceous deposit is burned off and the catalyst regenerated, and bucket elevators to transfer catalyst from the bottom of the kiln to the top of the reactor and from the bottom of the reactor to the top of the kiln. Auxiliary equipment includes a compressor to supply inert gases for sealing the top of the reactor from atmosphere, an air blower and line burner for supplying combustion air to the kiln, and a steam generating system in which water is pumped through the kiln cooling coils, after which the steam generated is disengaged in a flash drum; an elutriator the purpose of which is to control the particle size of the catalyst being circulated; a fresh catalyst makeup hopper and facilities for supplying fresh catalyst to the hopper, and a fines storage bin.

Catalyst is supplied to the reactor through a vertical pipe approximately 50 feet in height, depending upon the pressure to be maintained within the reactor. This pipe, called the seal leg, has a hopper at the top end into which the elevator discharges. This hopper is maintained full of catalyst so that the seal leg also remains full of catalyst at all times. It is therefore possible to operate the reactor at a pressure as high as 15 pounds/sq. in. with the upper end of the seal leg open to atmosphere with catalyst flowing downward through the seal leg against the higher pressure below and without discharging oil vapor to atmosphere. The kiln operates under a pressure not more than 1 pound/sq. in. above atmospheric and usually less and is therefore an inherently safe piece of equipment.

TCC reactors up to the present time have been operated with hydrocarbon vapors flowing counter-current to the descending flow of catalyst, but the flow in this respect may be either countercurrent or concurrent and the choice is a matter of operating conditions desired in any particular plant.

Like all the other cat-cracking systems the first TCC units were designed for large-scale operations, and were thus beyond the reach of the smaller refineries; and like other engineering firms in this field, the Houdry Process Corporation has taken the needs of these small plants under serious consideration.

The designing of a TCC unit for capacities in the range of 1000 to 5000 barrels/day posed the problem of retaining all the inherent simplicity and safety features of the larger TCC units and at the same time provide a low cost unit. Actually it has developed that the features of simplicity and low cost are closely related so that in the small TCC units now available, simplicity and safety have been retained and the cost reduced well below that of the scaled-down versions of the conventional early designs. These results were obtained by condensing the size of the equipment, combining equipment where possible and omitting features and equipment proved unnecessary by experience. The reactor, hot catalyst storage drum, and reactor feed hopper are built and erected as one vessel at a marked saving in cost. It has been found possible to use a single elevator for transporting the spent and the regenerated catalyst. A considerable saving in structural steel is accomplished by using the kiln and the reactor as supports for all platforms and elevator guides.

The operation of a TCC unit presents various features. The new small units will operate on natural clay or synthetic catalysts interchangeably. At constant throughput the operation of the reactor is controlled by three variables: the catalyst temperature entering the reactor; the catalyst circulation rate, and the temperature of vapor entering the reactor.

One notable feature of the TCC process is the high yield of useful products per unit of feed disappearance and per unit of catalyst deposit. Liquid recoveries (gasoline plus butanes plus cycle gas oil) range from 97 to well over 100 percent, depending upon the character of the charging stock and the conversion employed. These high liquid recoveries are obtained by operating at conditions where catalytic action can be maintained at a maximum and deleterious thermal side reactions kept to a minimum. These operating conditions require the maintenance of relatively high catalyst activity and, for very high conversions, recycling of catalytic gas oil.

Maintenance of a high catalyst activity is a prime requisite for the maximum success of a TCC unit. The TCC regenerating kiln has certain particularities of design and operation for accomplishing this object. The Thermofor kiln regenerates in stages or zones each having its own air and coolant control. The portion of the catalyst deposit containing high concentrations of material other than pure carbon is removed in the initial stages at low temperature conditions (875-975°F). Thus, water vapor and oxides of impurities such as sulphur are removed from the regeneration process before any high temperature combustion occurs. It then becomes possible to reactivate the catalyst fully by burning off carbon to a very low residual concentration on catalyst without incurring losses in activity from high-temperature contact with steam or sulphur compounds. This stage burning allows high catalyst activity maintenance with relatively low catalyst replacement rates. Performance on commercial units throughout the war program has demonstrated the practicability of maintaining activities of 30-31 A.I. for clay with 0.5-0.6 lbs./bbl. make-up and 34-36 A.I. for synthetic catalyst with 0.15 to 0.27 lbs./bbl. make-up.

How this provision for regeneration reacts to show the effect of catalyst activity on gasoline yield, liquid recovery and coke production at constant gas oil disappearance may be seen from the following small table:

Catalyst Activity Index	28	32
Conversion	60.0	60.0
Temperature	860	860
Gasoline—Vol. %	46.0	48.4
Liquid Recovery—Vol. %	99.2	100.9
Coke—Wt. %	4.0	3.6
Dry Gas—Wt. %	7.6	6.8

In the case of installation in smaller refineries recycle Thermofor catalytic cracking requires only moderate recycle ratios to produce gasoline yields far beyond the reach of thermal processing methods. The quality of such gasoline is as good as or better than that produced by single pass operation and the increase in investment cost is minor in relation to the substanital gasoline yield increase. In many cases this type of operation can be readily fitted into existing thermal cracking equipment at a considerable saving in investment cost. A table is presented below showing yields for single pass operation and for recycling at 0.5/1 and 1.0/1.0 (Recycle/fresh feed) ratios on a typical Mid-Continent wide cut gas oil using 30 A.I. clay catalyst.

Recycle/fresh feed ratio		0/1	0.5/1.0	1.0/1.0
Debutanized Motor Gasoline	Vol. %	42.0	56.0	64.8
Total B-B	Vol. %	10.0	12.8	15.3
Cycle Gas Oil	Vol. %	46.0	28.0	15.0
Dry Gas	Wt. %	6.5	8.0	9.6

To illustrate the advantages to be gained by the installation of TCC equipment Houdry Process Corporation has prepared an economic study for what is considered a typical refinery situation. It has been assumed that a refinery processes 5000 BPCD of typical Mid-Continent type crude in topping, two coil thermal cracking and naphtha reforming equipment. The two cases illustrating TCC processing are based on revamping of existing equipment and addition of a TCC reactor-kiln section for processing the material presently going to two-coil thermal cracking. The cases considered are briefly outlined as follows:

Base Case

Present operation, crude topping, two coil reduced crude cracking, deep naphtha reforming and catalytic polymerization of C_3 and C_4 unsaturates.

Case "A"

Crude topping, moderate naphtha reforming, TCC 1/1 recycle cracking of overhead from flashing reduced crude with integral visbreaker circuit for flash tower bottoms; catalytic polymerization of C_3 and C_4 unsaturates.

Case "B"

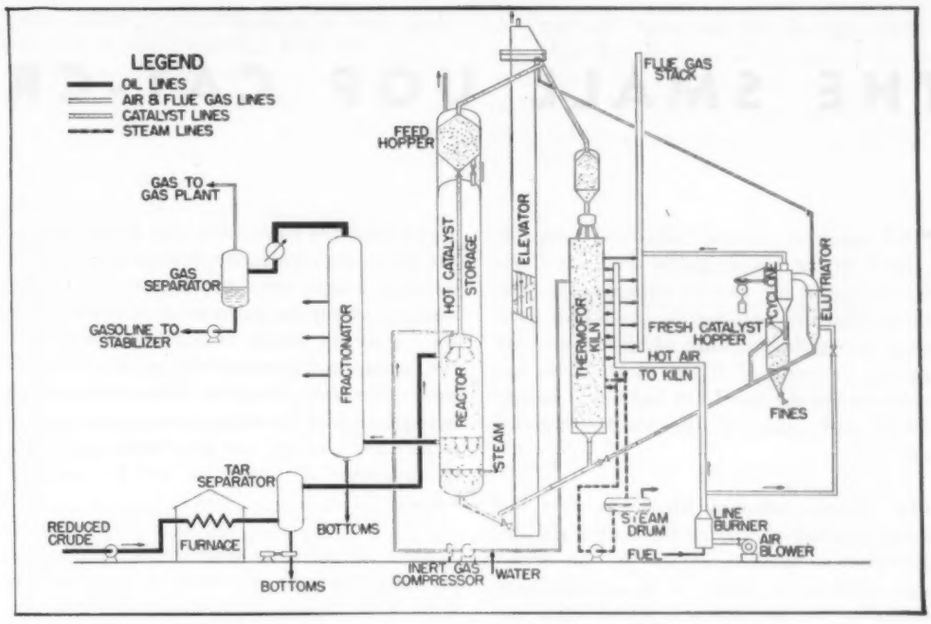
Crude topping, mild naphtha reforming, TCC 1/1 recycle cracking of overhead from reduced crude flash and vacuum flash towers; catalytic polymerization of C_3 and C_4 unsaturates.

The cases presented are based on the assumption that 600 BPCD (12%) of kerosene would be marketed. The price structure and utility values used are listed below:

Feed and Products	Price
Mid Continent crude	$ 1.40 /bbl.
Housebrand gasoline (78 CFR-M)	6.00c/gal.
Premium gasoline (83 CFR-M)	7.00c/gal.
Kerosene	4.25c/gal.
Fuel Oil (#6)	$0.90 /bbl.
Excess Butanes (above 10# RVP gasoline)	1.45c/gal.
Fuel Gas	15.00c/MMBtu
Utilities	
Steam (H.P.)	$0.24/M lbs.
Power	0.70c/KWH
Cooling Water	0.50c/M gal.
Treated Water	$0.15/M gal.
Clay Catalyst	4.00c/lb.
Labor (Average Rate)	$1.30/Man Hour

The gasoline price of $6.25/Gal. is based on 75% Housebrand (77.5 CFR-M) @ 6.00c/Gal. and 25% premium (83 CFR-M) @ 7.00c/Gal.

Table I gives a complete summary of overall refinery economics for the three cases considered. Case A shows a payout period of 2.5 years based on the new investment required. Case B, on the basis of cutting back asphalt for fuel oil production, shows a slightly lower return a large investment. This case however, gives greater flexibility in that fuel oil, or asphalt, or both may be produced as market requirements dictate. Evaluation of asphalt product at any price higher than fuel oil value will, of course, increase the earnings of this case.



Simplified Flow Diagram of Typical TCC Catalytic Cracker for Small Plants.

The major effects of the catalytic installation are a slight increase in catalytic polymer, butanes and light straight run and a decrease in reformed naphtha. Cracked gasoline, thermal or catalytic, remains nearly constant, being slightly higher in Cases A and B than the base case. The lower reformed naphtha and the higher butanes in the gasoline are explained by the fact that with the installation of the TCC equipment, it is not necessary to reform as severely as in the thermal case to reach the same octane level and lead requirement for the motor fuel. The reforming operation has, therefore, been reduced both in charge rate and severity. This results in a smaller quantity of lower octane number reformed naphtha and a greater requirement of butanes to make constant vapor pressure total gasoline.

Table I

Summary of TCC Economics

Case No. : Revenue	¢/Gal.	Base Case B/CD	Base Case $/Day	"A" B/CD	"A" $/Day	"B" B/CD	"B" $/Day
REVENUE							
10# RVP Motor Gaso.	6.250	2,814	7,387	3,467	9,101	3,499	9,185
Kerosene	4.250	600	1,071	600	1,071	600	1,071
Residual Fuel	2.145	1,210	1,089	727	654	687	618
Dry Gas (F.O.E.)	2.145	437	393	287	258	271	244
Excess Butane	1.450	....	....	26	16	12	7
Total Revenue			$ 9,940		$ 11,100		$ 11,125
OPERATING COSTS							
Crude	3.33	5,000	$ 7,000	5,000	$ 7,000	5,000	$ 7,000
Crude Distillation		5,000	300	5,000	300	5,000	300
Vacuum Reduction		....	....	....	....	750	89
TCC Cracking		....	....	2,412[1]	670	2,450[2]	612
Thermal Reforming		900	168	640	146	640	146
Thermal Cracking		2,750	400	....	....	....	....
Debutanization		....	18	....	20	....	20
Catalytic Poly.		92	115	166	153	170	157
Gasoline Inhibitor		2,814	3	3,467	3	3,499	3
Taxes, Interest, Ins. (Incremental)			21		134		154
TCC Royalty		....	....	2,412	121	2,450	123
Thermal Royalty		2,750	83	....	....	....	....
Cat. Poly. Royalty		92	19	166	35	170	36
TEL To 79 CRF-M (HCC's)		355	638	233	419	220	396
Total Operating Costs			$ 8,765		$ 9,001		$ 9,036
Earnings/Day			1,175		2,099		2,089
Differential Payout Period					2.45 yr		2.92 yr.
INVESTMENTS (Process Equipment Only)							
Revamp Thermal & Install TCC Catalytic Section					$775,000		$ 800,000
Catalytic Polymerization			$150,000		200,000		200,000
Vacuum Distillation			....		....		125,000
Total			$150,000		$975,000		$1,125,000

[1] Visbreaking and 1:1 Recycle Cracking
[2] 1:1 Recycle Cracking

THE SMALL UOP CAT-CRACKER UNIT

THE catalytic cracking units now being offered by the Universal Oil Products Company for use by the smaller refineries has been evolved from the large installations which were erected during the war, and which had nominal capacities in excess of 10,000 B/D. Even before the end of the war UOP had begun experimenting with units in the smaller capacity ranges.

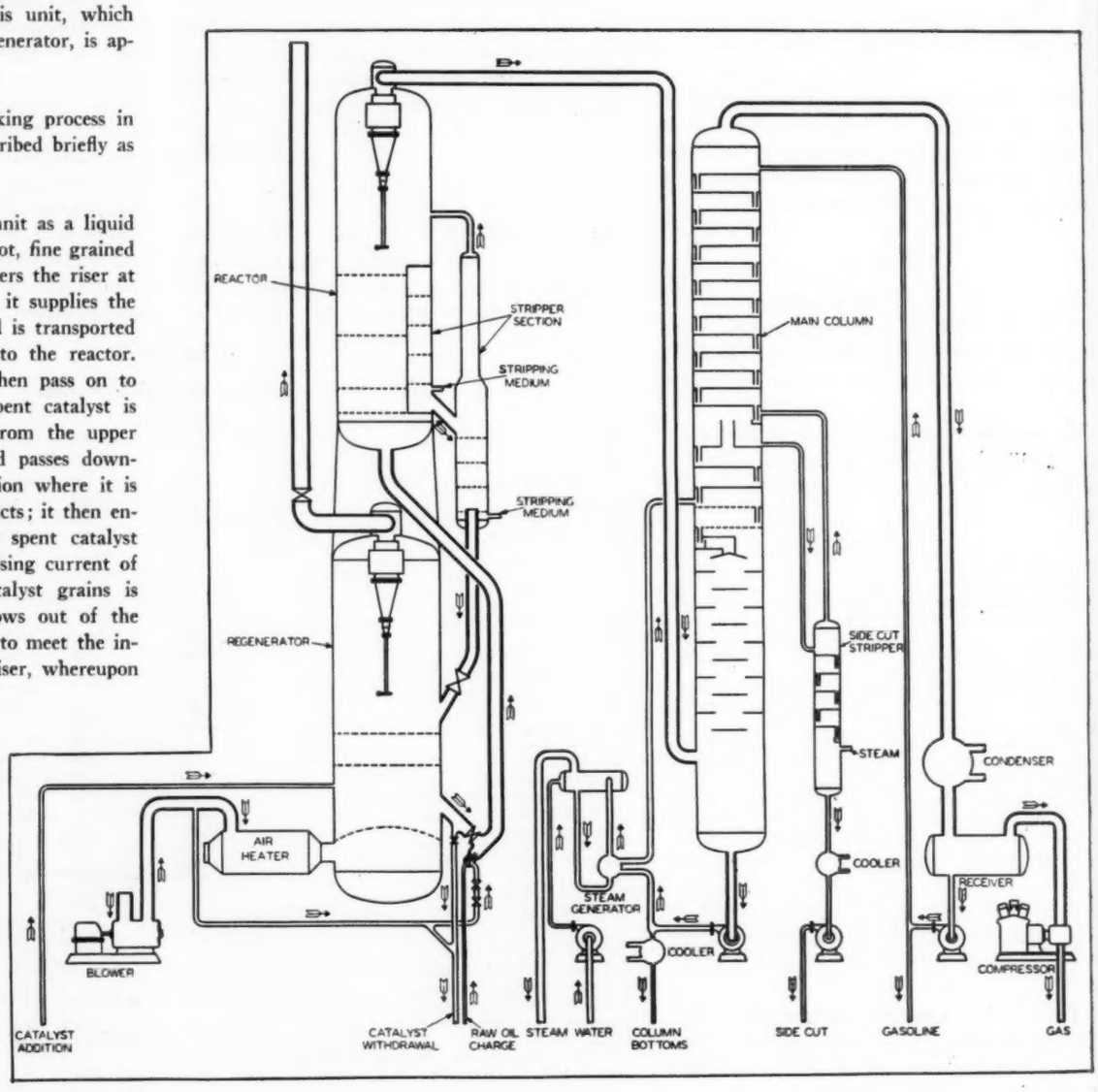
Earlier designs followed what was then the standard practice of erecting the reactor and the regenerator as separate vessels. In the newer design which is here shown in the accompanying illustrations, the regenerator is placed below the reactor and in the smaller sizes can be supported by the regenerator, thus eliminating the heavy structure required for support in the older design. The overall height of this unit, which combines the reactor and the regenerator, is approximately 125 feet.

The course of the catalytic cracking process in this UOP apparatus may be described briefly as follows (see the flow sheet):

The oil feed is charged to the unit as a liquid at the base of the reactor riser; hot, fine grained catalyst from the regenerator enters the riser at the point of oil injection, where it supplies the heat required by the process, and is transported upward by the vaporized oil into the reactor. The cracked reaction products then pass on to the fractionator. Meanwhile, spent catalyst is continuously being withdrawn from the upper reaction zone in the reactor and passes downward through the stripping section where it is stripped free from reaction products; it then enters the regenerator. Here the spent catalyst continues downward against a rising current of hot air, the carbon on the catalyst grains is burned off, and the catalyst flows out of the lower section of the regenerator to meet the incoming raw oil in the reactor riser, whereupon the cycle is repeated.

The products of combustion (flue gas) pass from the top of the regenerator through an internally mounted cyclone separator to recover entrained catalyst. A similar separator is installed inside the top of the reactor to recover catalyst from the gaseous reaction products on their way to the fractionator. However, these cyclones may be replaced by a scrubbing arrangement or both cyclone and scrubber may be omitted, depending on the choice of catalyst, as will be explained below.

In these operations the reactor temperature automatically controls the flow of hot catalyst through the regenerated catalyst slide valve into the reactor. The level of catalyst in the reactor automatically controls the flow through the spent catalyst slide valve. The reactor pressure is set by the gas compressor. The regenerator pressure is held constant by the rate of release of flue gas, with the valve in the flue gas line controlled by the pressure difference between the reactor and regenerator. This method of control is used on the 2600 B/D unit. The conversion or cracking reaction, as measured by the percent yield of cycle stock or by the gas rate, is controlled by varying the reactor level or temperature. An increase in either the reactor level or the temperature increases the conversion. In order to control the burning reaction an analysis of the regenerator outlet gas stream is obtained and the carbon content of the catalyst is determined periodically. The regeneration is then controlled by varying the air or carbon production rate.



Flow Diagram of the UOP Improved Fluid Catalytic Cracking Unit.

The present design of the UOP small unit represents a general simplification of small piping and the elimination of the heavy supporting structure; a number of the large transfer lines have been shortened and the old regenerator riser has been abolished. The number of expansion joints has been reduced from 9 to 2. The efficiency of processing, regenerating and stripping has been improved by addition of grid plates in these three sections of the unit. The additional grid plates in the reactor reduce the formation of bubbles and improve the efficiency of contacting the oil and catalyst, thereby increasing the liquid recovery. In addition, the geometric proportions of the stripper have been changed to increase the ratio of the length to the diameter; tests have shown that a high ratio of length to diameter increases stripping efficiency.

All these improvements add up not only to increased processing efficiency but also to decreased cost of the unit. An important factor in this cost reduction is the fact that the regenerator can now be operated at 15 pounds pressure per square inch. This higher pressure in the regenerator has permitted a reduction in the sizes of the vessel and the pipe lines because of the decreased volume of gas.

All the various existing systems of catalytic cracking lay proper emphasis on the nature and physical properties of the catalyst. Naturally preference is given to the most efficient available catalyst, meaning the most efficient under a given set of conditions, technological and economic.

In the UOP system three categories of catalyst come into consideration, a natural clay catalyst, which is the cheapest, and two synthetic catalysts; one of these synthetics is a silica-magnesia compound, the other a silica-alumina compound.

These synthetic catalysts are now prepared in a microspherical or MS form, which is more nearly uniform in particle size which flows easily. The ground natural catalyst has sometimes been difficult to retain in the unit. Use of the microspherical catalyst permits design of the unit without secondary catalyst recovery equipment, such as a Cottrell or oil scrubber or slurry pumps. However, since the cost of catalyst is an important factor in calculating the earning power of any catalytic cracking unit, and since the natural catalyst powder is lower in cost than either of the synthetic catalysts, its use must also be considered in the design of the unit; and when used, provision must be made for secondary recovery of the catalyst. Further, since the character of the cracked products produced by the three kinds of catalysts show differences, the choice among them will be more or less dictated by the refinery program.

The flexibility of the UOP fluid process has been demonstrated by the units now in operation. As mentioned previously, a given unit can be operated at various conversion levels. Table I shows typical yields obtainable in both once through and recycle cracking of 31°API gravity gas oil over silica-magnesia catalyst. The first two columns of the table show that the debutanized gasoline yield can be increased from 53 to 56% at the expense of gas production by recycling at a constant conversion of 65%. This operation may be carried out by reducing the level of the catalyst in the reactor and returning a part of the unconverted gas oil to the reaction zone. The last column of the table shows the yields which are obtained when the conversion is increased to 80% by recycling and increasing the amount of catalyst in the reaction zone. In this case the total 10# RVP gasoline yield, including polymer, amounts to about 73% of the gas oil charged.

Table II shows the effect of reactor temperature on the octane numbers of the gasoline produced at a constant conversion of 65%. Increasing the temperature from 825° to 975°F. increased the motor method clear octane rating about three points, had no effect on the leaded motor method rating, but increased both the clear and leaded research ratings considerably.

The utility requirements for the improved unit depend upon the type of operation and type of equipment used for heat exchange, pumping and compression. As a basis for discussion, the normal utility requirements were estimated for the catalyst and fractionating sections of a 2000 B/SD unit processing gas oil at an intermediate conversion once-through operation.

The utilities required to operate this equipment are estimated as follows: the total steam required amounts to 4000 lbs./hr., but 5500 lbs./hr. of steam is produced from the column bottoms steam generator, resulting in a net steam production of 1500 lbs./hr. All of the pumps are driven by steam and the air compressor by a gas engine.

The total heat available in the fuel gas produced after polymerization would amount to 31 MM Btu/hr. It is estimated that 3 MM Btu/hr. of fuel gas would be used in driving the gas compressors required to feed the low pressure receiver gas into an absorber operated at 200 Psi. An additional 5 MM Btu/hr. of gas is used for compression of the regenerating air. The net fuel gas available for the boiler house, or heating in other sections of the refinery, thus amounts to 23 MM Btu/hr. The total cooling water for the condenser and coolers amounts to 500 GPM. The electricity required for lights and power is estimated at 15 KW.

Using these utilities as a basis, the estimated cost of operating this equipment is summarized in Table III. The total cost of operation amounts to 29.3c/bbl. of raw oil charge. This cost includes labor, maintenance, catalyst, royalty, and taxes and insurance. Credit was taken for the net steam production in these calculations, but no credit was taken for the fuel gas production. With the operation of a stabilizer and absorber to prepare debutanized gasoline and a liquid C_3-C_4 feed to the polymerization unit, the total operating cost would be approximately 33c/bbl.

TABLE I

UOP Fluid Catalytic Cracking 31° API 400-850°F. Gas Oil Silica-Magnesia Catalyst

Operation	Once Through	Recycle	
Conversion %	65	65	80
Yields, Vol. %			
Debutanized Gasoline	53.0	56.0	62.0
Cycle Oil	35.0	35.0	20.0
Butylenes	5.5	5.3	7.1
Butanes	5.5	3.2	5.1
Propylene	3.8	3.6	5.1
Propane	1.9	1.7	2.7
C_3 and Lighter Gas, Wt. %	1.9	1.8	2.9
10 Lb. RVP Catalytic Gasoline	55.9	59.0	65.2
10 Lb. RVP Polymer Gasoline	6.0	5.9	8.1
Total 10 Lb. RVP Gasoline	61.9	64.9	73.3
Octane Numbers of 10 lb. Catalytic Gasoline			
Motor Method Clear (F-2)	79.8	78.2	79.2
+ 3 cc. TEL/Gal.	86.7	85.0	85.5
Research Method Clear (F-1)	89.7	89.7	91.2
+ 3 cc. TEL/Gal.	96.3	96.3	97.4

TABLE II

Effect of Reactor Temperature on Octane Numbers of Gasolines Produced in UOP Fluid Catalytic Cracking

Conversion (Gas Oil Disappearance)	——	65	——
Reactor Temperature °F.	825	900	975
Octane Numbers of Debutanized Gasoline			
Motor Method (F-2) Clear	78.1	80.3	81.4
+ 3 cc. TEL/Gal.	86.5	86.5	86.5
Research Method (F-1) Clear	85.0	90.8	94.0
+ 3 cc. TEL/Gal.	94.1	96.5	97.5

TABLE III

Summary of Operating Costs 2,000 B SD Fluid Catalytic Cracking Unit

BASIS: 60% Conversion Mid-Continent Gas Oil Catalyst Section. Fractionator, and Gas Compressors.

Item	$/CD
1. Operating Supervision	
Foreman @ $350/mo.	11.70
2. Operating Labor	
1 Operator @ $1.50/hr., 24 hrs.	36.00
2 Helpers @ $1.25/hr., 48 hrs.	60.00
3. Utilities	
*Steam 1500 lbs./hr. @ 25c/M lbs.	8.10
Fuel gas 8.0 MM Btu./hr. @ 15c/MM Btu.	25.90
Water 500 GPM 1c/M gal	6.50
Electricity 15 KW @ 1c/Kw	3.20
4. Catalyst	
½ lb./BCD chg. @15c/lb.	135.00
5. Maintenance (Labor & Materials)	100.00
6. Laboratory	
1 Tester 24 hrs. @ $1.00/hr.	24.00
Chemicals, materials, etc.	10.00
7. Royalty	
1800 B/CD @ 5c/bbl.	90.00
8. Taxes & Insurance	35.00
TOTAL	$528.20
Cost per barrel of charge	29.3c

*Credit

CYCLOVERSION FOR THE SMALL REFINER

IN the past year special emphasis has been given to adapting Phillips Petroleum Company's Cycloversion Catalytic Cracking Process to post war refining problems. The process has, therefore, taken on a broader process aspect than that of a strictly catalytic cracking scheme for gas-oil feed stocks. The various factors to be considered in planning future operations are complex and as a consequence, refiners both large and small have undertaken economic studies on alternate bases in anticipation of a more or less stabilized post-war economy. The Perco Cycloversion Process may be adapted to improve yields and octane values on a wide variety of stocks as confirmed by both commercial and pilot plant data. The process is economical in capacities as low as 1,000 to 1,500 b/d depending, of course, on charging stock and utility costs and subject to changes in labor and material markets.

Reference to the accompanying flow diagram shows the fresh feed being charged to the furnace, preheated, and passed to the reactor or catalyst chamber at 980°-1000°F. A small amount of diluent in the form of water or steam is added in the convection bank of the furnace. This diluent assists in vaporizing the feed and increases the octane rating of the gasoline. The superheated oil-steam mixture passes from the furnace to the reaction chambers wherein cracking or reforming is accomplished. The reactors are operated at about 85 psig and reaction periods or process cycles range from 2-10 hours for cracking and 24 hours or more for naphtha reforming. The reaction chamber effluent passes to waste heat exchangers for heat recovery in the form of steam, thence to heat exchange and condensing equipment and as liquid product passes to the vapor-oil-water separator. From the vapor-oil-water separator, the hydrocarbon condensate goes to product fractionation, while the water is withdrawn and the gases goes to the absorption or vapor recovery unit.

The steam system comprises, in addition to the waste heat exchangers, a steam drum and other auxiliaries. The steam as produced on the unit may be used in catalyst regeneration and a unit may be designed to be economically self-sufficient with respect to its entire steam requirements.

For catalyst regeneration, steam is superheated to about 850°F, admixed in proper proportions with air, and passed to the reactor being regenerated. The steam-air mixture effects regeneration of the catalyst by burning off carbon, etc., restoring it to its normal catalytic activity. Repeated regeneration of the catalyst in light of commercial experience does not appear to degrade the activity of the catalyst nor otherwise render it unsuitable for use, resulting in low catalyst replacement costs.

The temperature in the regeneration cycle is controlled in the range of 1100-1400°F. by regulating the quantity of air added to the superheated steam. A high regeneration temperature using steam as a diluent results in considerable water-gas reaction thereby reducing the total air required for a given quantity of carbonaceous material to be burned off. The products of regeneration in passing from the catalyst case are utilized in the production of steam in the waste heat exchanger, thus effecting steam production in both process and regeneration periods. Regeneration with circulation of the flue gas instead of steam may be used, depending on the economic considerations.

The foregoing described operation results in improved yields and higher octane motor fuel stocks as evidenced by the data recorded in the accompanying tables. Table 1 records the Cycloversion cracking of a Texas Panhandle gas-oil at two version levels. It is to be noted that with this feed, little change is realized in the quality of products with the deeper conversion level, the principal difference being the greater volume of catalytic gasoline with attendant greater gas production and carbon deposition on the catalyst.

TABLE 1

Charging Texas Panhandle Gas Oil

Conversion, Signel pass, Vol. %	50.5	62.9
Temperature, °F	984	1010
Pressure, psig	78	85
Process Period, Hrs.	10	4
YIELDS, PER CENT OF CHARGE		
Catalytic Gasoline, 400 E.P., Vol. %*	39.7	45.2
Propylenes, Vol. %	3.8	5.4
Butylenes, Vol. %	4.2	6.0
Catalytic Recycle; 400 +, Vol. %	49.5	37.1
Gas, F.O.E., Vol. %	9.0	12.9
Carbon, wt. %	1.7	2.6
INSPECTION TESTS		
Feed:		
Gravity, °API	36.5	36.6
Distillation		
10%	472	510
90%	735	717
Aniline No.	186	182
Catalytic Gasoline*		
Gravity, °API	60.3	60.3
Reid Vapor Pressure	10.0	10.3
ASTM Octane No.	77.0	76.3
+3cc TEL	81.8	82.9
Research Octane No.	86.8	86.2
+3cc TEL	93.1	93.1

*Includes Butanes remaining after Catalytic Polymerization of Butylenes

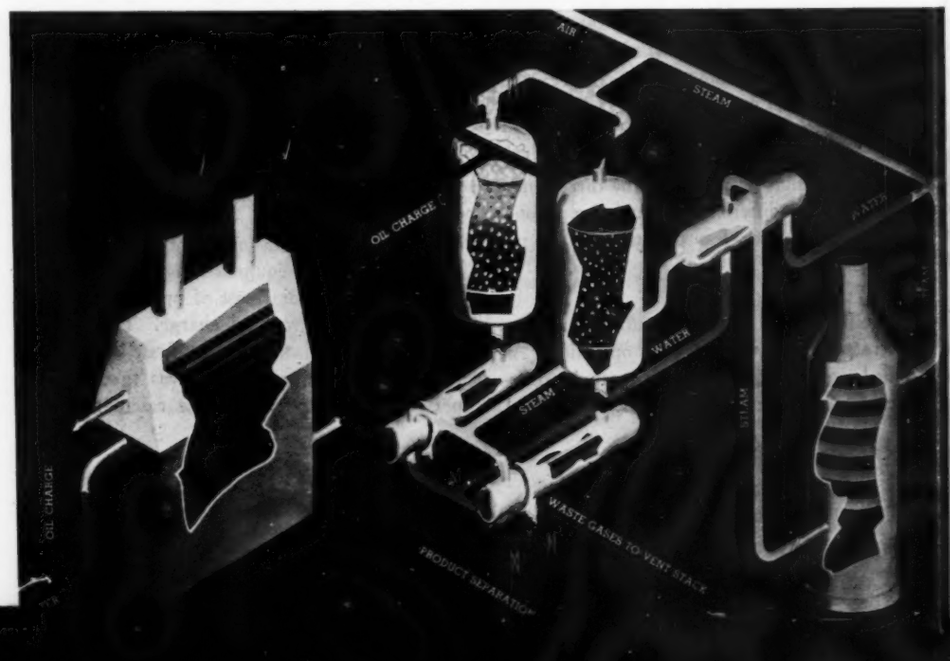
Table 2 is a resume of inspection data on several Cycloversion reforming tests. The feed for such a unit may be either cracked or straight run

(Continued on page 126)

TABLE 2

Charging Straight Run Naphtha

Naphtha Source	Pennsylvania		Mid-Continent		West Texas	
Temperature, °F	1015		990		1015	
Pressure, psig	50		15		50	
Process Period, Hours	24		15		24	
YIELDS, VOL. % OF CHARGE						
Catalytic Gasoline, C_4-400EP	92.9		98.0		95.0	
Dry Gas, f.o.e.	6.4		3.2		5.4	
INSPECTION TESTS	**Feed**	**Catalytic Gasoline**	**Feed**	**Catalytic Cracking**	**Feed**	**Catalytic Cracking**
Reid Vapor Pressure	3.5	10.2	4.0	10.1	2.6	8.3
Gravity, °API	62.2	62.8	59.0	59.0	54.8	55.1
Total Sulfur, wt. %	0.055	0.005	0.037	0.008	0.140	0.008
Distillation						
IBP	100	88	121	98	144	100
10%	156	137	189	165	198	165
50%	262	248	254	259	259	245
90%	353	343	321	325	343	331
E.P.	404	409	366	377	394	406
ASTM Octane No.	48.8	61.5	41.1	55.3	56.0	68.3
+ 1 cc TEL	57.3	71.0	53.5	68.8	63.6	77.5
+ 3 cc TEL	67.1	79.6	67.0	78.4	70.0	83.1
Research Octane No.	49.6	65.8	. . .	. . .	59.1	74.3
+ 1 cc TEL	57.9	74.4	. . .	. . .	66.0	83.2
+ 3 cc TEL	68.7	83.5	. . .	. . .	72.1	88.4



A BRITISH REFINERY IN WARTIME

Expansion and Development Achieved Under War Handicaps to Maintain Flow of Specialized Products to the British Fighting Forces.

THE annual Refinery number of World Petroleum for 1938 carried a full account of the then newly-completed plant of the Manchester Oil Refinery, England. Shortly afterwards, the war clouds gathered and the storm broke.

The refinery was built just outside Manchester on the ship canal which penetrates from the west coast to the heart of industrial England. As well as giving easy access to ocean-going tankers, the site was chosen primarily because of its position in the center of Britain's major industrial consumers of lubricating, transformer and technical white oils. Prior to the war, the bulk of these oils for British use, plus the total requirements of liquid paraffin, were obtained from abroad, mainly from Germany.

Planned originally for the production of high-grade lubricating, transformer and technical white oils, the Manchester plant was designed from the outset for a dual purpose: to deal with a great variety of crude charging-stocks, and to be capable of adjusting the yield of finished products to fit the ever-changing demands of industry.

War necessitated a rapid revision of the production program to meet new specifications. To achieve this, the refinery's adaptability was exploited to the full. In addition, due to foresight in design, it was possible both to increase and to extend the scope of activities, and to manufacture the multitude of new products demanded by the emergency.

For six years, in the face of bombing, blackout and other war handicaps, the plant handled an ever-mounting series of products, through the machinery of the British Petroleum Board, to meet the urgent demands of the land, sea and air forces.

The first operating difficulty encountered was that of the total blackout imposed over England from the outset. Restrictions were rigidly enforced. The normal method of open-window ventilation had to be discontinued immediately and replaced by a forced draft system. Delays in delivery of needed equipment created additional hardships for personnel, which were met with uncomplaining fortitude.

Very soon, transportation became erratic as communications were disrupted by enemy action. This problem was further complicated by the vastly increased volume of small packages destined for use by the Services. These packages had to be dealt with on equipment which had previously handled only one-third of the tonnage.

When bombing was at its height the manpower shortage made itself felt. The first calls for military conscription were met mainly from the clerical workers' ranks, as these had lower deferment priority than operators. The labor call-up then made inroads into the operating staff. The loss of man-hours had to be made up by the redoubled efforts of remaining personnel and by working longer shifts. At the same time, civil defense services required more and more of the off-duty hours of the workers.

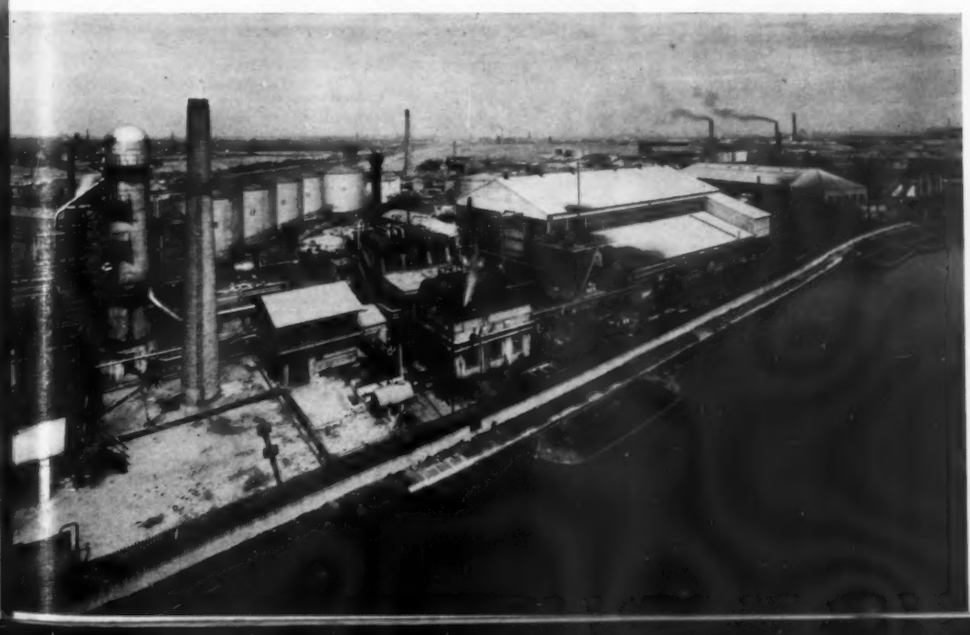
Alongside the refinery, the Barton power station in spite of elaborate camouflage, provided an aiming mark for enemy bombers with its two huge 300-foot chimneys. At the height of the "blitz," German raiders passing nightly over the area, on their way to strafe the Liverpool docks, jettisoned their cargoes around Manchester when attacked by ack-ack and night fighters. Others dropped their loads haphazard when they saw beneath them the industrial area of Trafford Park, in which the refinery is located.

One worrying night, with the plant working to capacity, a 250-lb. bomb landed at the base of the vacuum fractionating column, tore through the surrounding girder structure and set ablaze the hot crude in the transfer line. Two others destroyed the adjacent gasoline tanks and fired their contents. The fires were quickly quenched by vigorous firefighting teams, intensively pretrained and equipped with the latest appliances.

At the same time, the night shift automatically put into operation the drill for immediate shutdown of the parts of the plant affected. Discipline, initiative and quick thinking were the keynotes of these emergencies. The benefit was reaped from the planned reserve of emergency repair stocks laid down for such an instance as the one quoted. In this particular case the damage was made good in just over three weeks and continuity of operation was thus barely impaired.

While all these problems were being faced and overcome the demand became more insistent for an increased output of specialized oils and products new to the refinery. Being an independent company, the board of directors were able to take rapid decisions for the furtherance of the war effort without having to consider group interests. In fact, during the period of the "phony war" in March, 1940, at a time when there were many doubts and apprehensions about the future course of events, the directors took an immediate decision to make a large capital expenditure on the construction of a new chemical treatment and technical white oil plant, and a considerable enlargement of the existing filling and blending plant. The work was put in hand with all speed and was continued without interruption throughout the harassing days of Dunkirk and the Battle of Britain. At the time when the Germans reached the Channel ports, and invasion of England seemed imminent, the construction staff were urged to press forward with even greater speed on these new projects.

General view of refinery taken in early 1939.



This faith in the invincibility of Britain was fully justified when, in twelve months time, the new sections of the plant came into operation and additional production was obtained for war needs of 2,500 tons of white oils, 1,700 tons of liquid paraffins, and 6,000 tons of heavy lubricating oils per annum. The importance of this far-sightedness cannot be over-emphasized when it is remembered that the large pre-war imports of white oils from Germany had, naturally ceased to arrive, and that liquid paraffins were not being produced by any other refinery in England. While the new chemical treatment plant was being built, the necessity arose for the construction of a plant for the preparation of petroleum sulphonates and sulphonic acids, from the materials contained in the by-products resulting from treatment of high-grade technical oils. These by-products, before the war, had been allowed to go to waste. The sulphonates production plant was finished and put into operation in a matter of months. From their application as essential components of soluble and non-corrosive cutting oils, the sulphonates were rapidly developed for use as emulsifiers, as cleansing agents and in special polishes.

Incorporated in the new petroleum sulphonates section was a unit for the recovery of ethyl alcohol, a basic material in large demand and very short supply, which was being used in the manufacture of specialized oils in the chemical treatment plant. This recovery unit succeeded in reclaiming approximately 60 percent of the alcohol used.

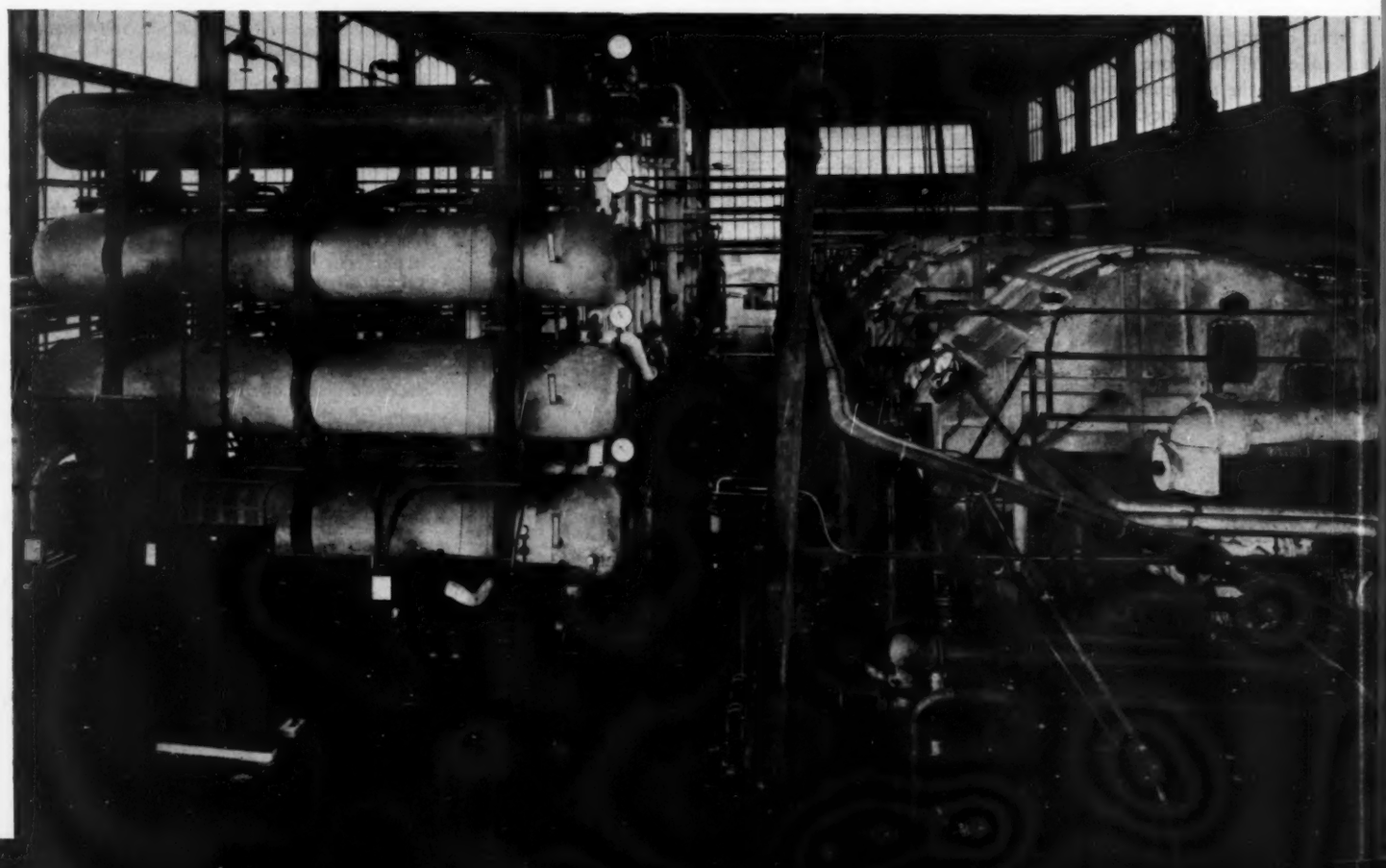
With the intensification of the enemy's U-boat campaign the British import position became perilous at various stages of the war. This necessitated maximum use of materials available inside the country. As a result a campaign was started to collect and re-treat stocks of used oil, which would normally have been scrapped. The material was put through all the refining processes usually connected with the production of lubricating oils, and a large tonnage of these waste oils was treated in the refinery between operations carried out on fresh deliveries of crude.

From the commencement of the refinery's operations the research department was planned on the most liberal scale to meet progressive modern requirements. Thus, when war brought the need for an even more intensified and redoubled research program, the staff was already fitted to meet the strain.

In England, up to 1939, technical white oils had been used chiefly in the cosmetic and food industries. Thereafter, they became essential armament materials. In co-operation with the Service departments, the refinery research staff developed from these oils special hydraulic fluids to withstand the exacting contrasts of desert and Arctic conditions and for stratosphere flying. Special oils were produced for use in the landing mechanisms and weapon equipment of fighter and bomber aircraft; low cold test corrosion inhibiting oils for the accurate operation of all the delicate instrument mechanisms used by the forces, requiring protection against rust and ice; new low temperature greases; oils and compounds for rust prevention of arms and equipment and for the preservation of service stores. Few, if any, of these oils were manufactured before the war, but toward its latter half the refinery was one of the largest producers of hydraulic brake fluids and hydraulic control oils. The research on the white oils brought them into important use as

Upper left: Chemical Treatment Plant Filter Press room.
Left: Chemical Treatment Plant Centrifuge Room.

View of Edeleanu Plant, showing settlers on left, filters on right.



carrier agents for spray oils and insecticides as an aid for agriculture in the all-out effort to increase home food production. In the textile industry, producing service clothing and equipment, artificial silk for parachutes and other synthetic fibres, improved lubricants were supplied for the machines.

Essential compounds such as aircraft control lubricants, recoil, refrigerator, torpedo and turbine oils were the outcome of the refinery's emergency-prepared research staff.

The mobile power stations of the British forces demanded a large supply of transformer oils. A considerable quantity was provided from this refinery and no instance was ever reported of a shut-down due to imperfect oils or failure of supply. During the long and exacting period of the Battle of the Atlantic, England relied on the production of Manchester Oil Refinery for the overwhelming bulk of her transformer oil supply. In addition, a continuous flow was maintained of large quantities of solvent-refined lubricating oils, conforming to rigid specifications and destined for use by the Navy, Army, Air Force and Merchant Navy. Many of the British fighter aircraft were lubricated with oils from this refinery.

The possibility of finding suitable replacements for raw materials, which previously had been obtained from abroad, already had been considered by the research staff. When the outbreak of hostilities cut off European supplies, the necessity became urgent and placed an additional task on the refinery. By-products, which, before the war, had been utilized as fuel or put to waste, were investigated. This resulted in the development of the use of the highly aromatic extracts obtained from the solvent extraction plant. These extracts were utilized as a partial replacement for linseed oil in paints, putty and core oils, and as a substitute for resin in paper sizing. They found a further application as rubber extenders, as plasticizers and softeners for new synthetic rubber and as part plasticizers for polyvinyl chloride compounds. Much of this latter work was carried out conjointly with other groups under the Petroleum Board Extracts Section.

From products of the petroleum sulphonates plant the research staff developed valuable new corrosion-inhibitors, emulsifiers, wetting and fat-splitting agents and other products which were essential war materials and normally would have had to be imported.

As a result of all this work more than 95 percent of the crude imported for the refinery was, and still is, being turned into marketable products.

Since the end of the war the refinery has continued in its progressive policy and the intensive war-time research program remains in operation to further the peaceful advancement of industry and to aid civilization emerging from the chaos of war.

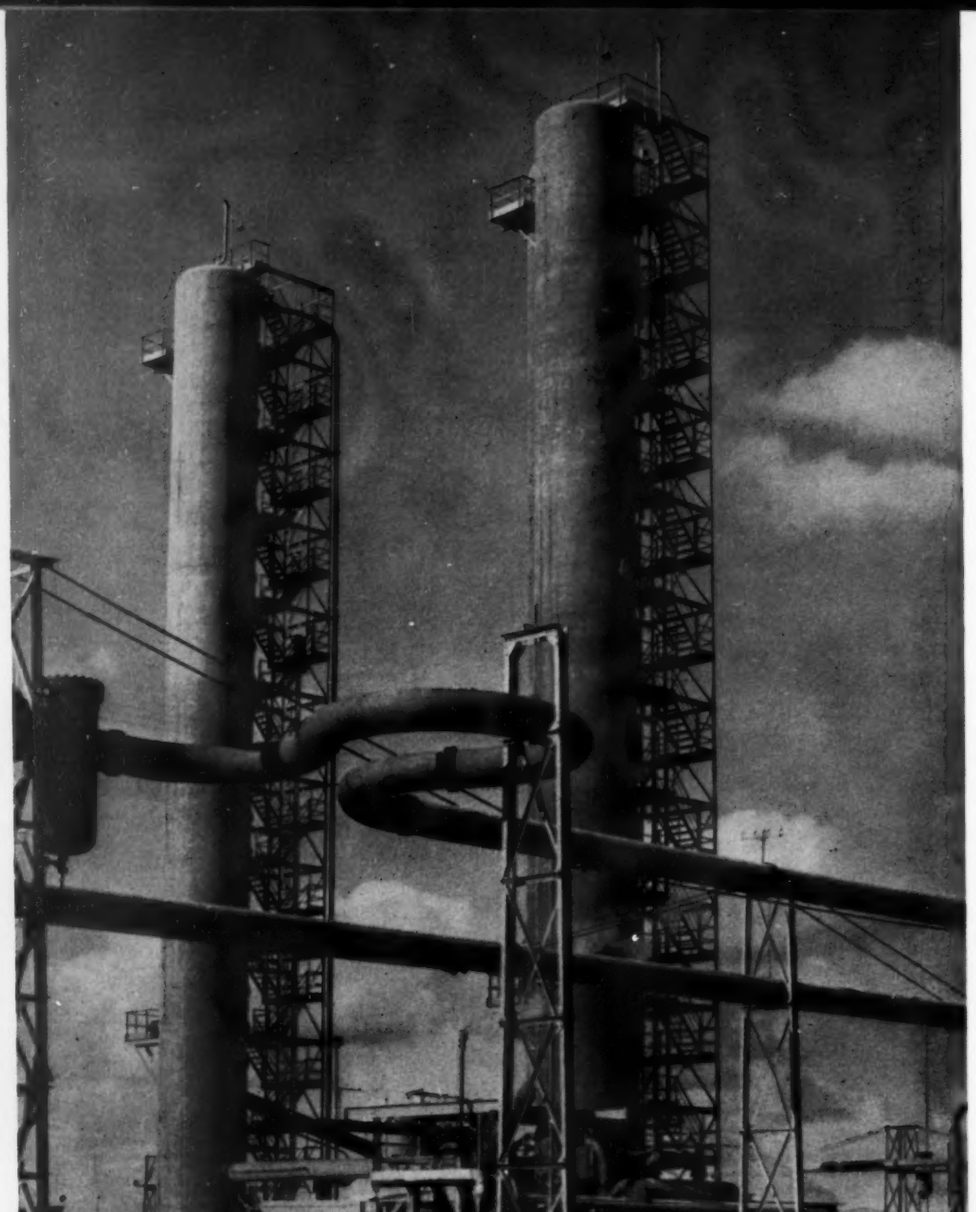
Distillation unit; main evaporator lines.

The art of "tailoring" oils to suit specific purposes is still young, and almost up to the present time the engineering industry has had to accept whatever quality of lubricating oils the refiner was able to produce. From now onward, the effort will be to shape the oils to meet specialized requirements. Manchester Oil Refinery intends to be at the fore-front of this effort.

The large team of chemists, physicists and engineers now at work at the refinery has a two-fold objective, for their immediate research: first, the improvement of existing main products; second, the development of chemical compounds from oil for the manufacture of new products.

Abreast with this is the high standard of technical service policy formulated by the company. This aims at a backing-up of all products with a staff of technical experts, ready to go straight to the scene of action where the products are used and to investigate and advise on any special problems. The technical service itself is backed by a team of chemists and laboratory research workers to examine specific industrial or consumer problems in detail.

As a concise indication of the scope and extent of the refinery's ingenious, and often improvised, expansion under urgent war-time conditions, the following list of products handled through the British Petroleum Board is given: aircraft control lubricant, aircraft engine oils, automobile petrol, bunker fuel oils, cable oils, compressor oils, cutting oils, diesel fuel, diesel lubricants, emulsifying cutting oils, engine oils, extreme pressure lubricants, fog oils, gear oils, grinding oils, heavy duty lubricating oil, hydraulic brake fluid, hydraulic control oil, illuminating oils, industrial lubricants, industrial fuels, insulating oils, kerosene, machine lubricants, medicinal oils, motor oils, non-carcinogenic oils for mule cotton spinning, petroleum, quenching oils, range oils, recoil oils, refrigerator oil, rifle bore cleaner, rust preventatives, sodium sulphonate soaps, solvents, tempering oils, torpedo oils, transformer oils, turbine oils, water-displacing compounds, waxes, white oils.



One Hundred-Plate Divided-Column Superfractionators

ABADAN EMERGES FROM WAR WORLD'S LARGEST REFINERY

A DESCRIPTION of Abadan Refinery as it stood in 1938 was published in the July 1938 issue of World Petroleum. Between that time and the outbreak of war in September 1939 the crude oil distillation capacity of the refinery was increased from 218,000 to 283,000 barrels per day by the installation of a 75,000 barrel atmospheric-vacuum distillation unit, similar to two of that size previously in operation. During the same period cracking and reforming capacity was raised to nearly 150,000 barrels per day by the addition of two thermal reformers of the polyforming type with a daily capacity of 24,000 barrels each. To meet wartime demands, the refinery was greatly enlarged. Its throughput capacity now is 360,000 barrels per day and its capacity for aviation gasoline production capacity is 30,000 barrels per day, making it the largest refinery in the world.

Abadan refinery, well situated in peacetime to serve Eastern as well as European markets, lived through widely fluctuating phases during the war years. Between 1939 and 1945 the annual gross output of products touched a low trough of 115,000 barrels per day in 1941 and a record high crest of 325,000 barrels in 1945. During this period aviation plus motor gasoline production was as low as 23,800 barrels per day and as high as 79,000 barrels per day. Residue type fuel oil production at the same time fluctuated from a low annual figure of 57,000 barrels per day to a top figure of nearly 152,000 barrels per day.

To meet such wide fluctuations, directly attributable to the effects of various phases of the war on supply and demand, called for a high degree of flexibility of operations which the company was able to meet through its policy of generous peacetime planning and through its facilities for recycling excess products to reservoir.

Prior to Italy's entrance into the war, considerable quantities of Persian oil were transported through the Suez Canal to Great Britain and certain Mediterranean zones. Following that, even well into the spring of 1941, a substantial amount of oil continued to be imported into the United Kingdom via the route around the Cape which kept up the output from Abadan to a reasonable level. Then, with a badly deteriorating shipping position the "short-haul" policy was adopted as essential to Allied war strategy, following which no further supplies of oil were sent from Abadan to Great Britain during the remaining years of the war. As a result, 1941 saw a drop in output to the lowest war year figure of 115,000 barrels per day of products.

At the end of 1941 came Japan's attack on Pearl Harbor and by the spring of the following year the oil producing areas of Burma and the Netherlands East Indies had been overrun. As a result Abadan was called upon to supply, almost alone, many of the areas previously served by oil from those countries. With the turn of the tide in Egypt, following El Alamein in October 1942, and with the growing ascendency of the Allied Air Forces in the Mediterranean area, the Suez Canal returned to use as a strategic waterway and once again oil products from Abadan entered the Mediterranean zone. This two-way expansion, both East and West, resulted in a steady growth of demand on the refinery which culminated in 1945 with a peak output of 325,000 barrels per day of products.

Undoubtedly, the most notable achievement of Abadan Refinery was the expansion of its high octane aviation gasoline production for military requirements. This rose from virtually nil in 1939 to a yearly rate of 27,000 barrels per day in 1945, of which 24,500 barrels was of the 100 octane variety and the balance at 90 octane number. Its importance to the Allied war effort can be gauged by the fact that some 85 percent of all the aviation spirit used by the American and British Air Forces in the Middle East and India-Burma combat zones derived from Abadan.

In 1939 production of aviation fuel at Abadan was all of 87 octane grade and was a blend of iso-octane, pyrolysis benzole, light aromatic extract derived from kerosene, iso-pentane and straight-run gasoline, with 3-cc. of TEL. per U. S. gallon; this product was all disposed of in the vicinity, to meet small local Air Force demands and the requirements of transport lines whose routes passed through the Persian Gulf.

With the outbreak of war attention was turned to ways and means of producing 90 and 100 octane gasoline for service aircraft. The first stage of evolution was a stocktaking of raw materials available in Persian crude, and from reforming and cracking operations, together with existing plant and equipment, with the object of harnessing raw products to the best advantage. At that stage specialty plant and equipment available which was suitable for aviation component production consisted of a condimer plant, a hydrogenation unit, a pyrolysis benzole unit and approximately 90 plates of superfractionation capacity.

The development plan selected was immediately put into operation, and by May 1940 the first 100 octane blend was approved and went into production at the rate of approximately 1,700 barrels per day. Concurrently with this, the fruits of many years of investigation by the company's Research Station on the production of "alkylate" were incorporated into the design of a plant largely improvised from vamping together a number of miscellaneous vessels and fractionating columns, made available at Abadan. This unit was rushed into production by the end of 1940. At the same time an SO2 kerosene extraction unit was adapted to extract aromatic from a naphtha cut ex the heavy motor gasoline range.

These two latter developments, coupled with the best available selection of gasoline components suitable for 100 octane manufacture, enabled Abadan to raise its output of high octane aviation gasoline to 3,400 barrels per day in 1941 and 8,500 barrels per day in 1942.

Parallel with making the most of resources available at Abadan, a detailed review of all known alternative means of producing 100 octane gasoline was made by the company's technical staff in Great Britain, with a view to assessing the best economic method of wide-scale expansion up to the practical production ceiling of the refinery.

This resulted in the selection of the following three main lines of development:

(1) Maximum C_4 alkylation (plus a proportion of C_5 alkylate)—coupled with C_4 isomerization.

(2) Segregation by superfractionation of iso-C_5, iso-C_6, and iso-C_7, from light crude oil distillates.

A Drilling Location at Agha Jari Illustrating Rough Terrain in this Area.

(3) SO_2 extraction of aromatics from virgin naphtha, with facilities to produce 95 percent aromatic extract.

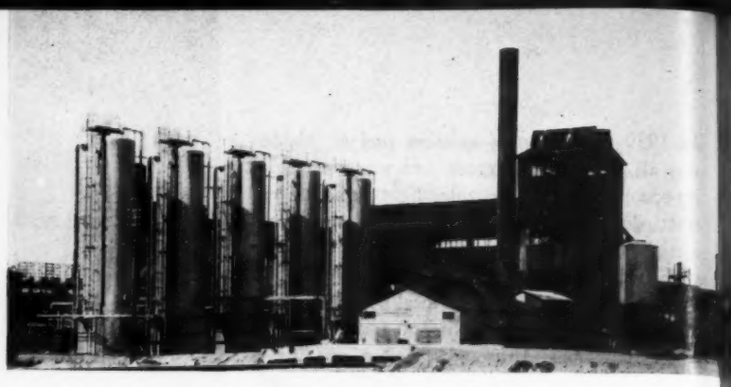
This combination called for only 1.9 tons of steel per barrel/day of output, a considerable saving compared with a catalytic cracking route, which resulted in agreement to proceed along the selected lines detailed above.

The equipment ordered was planned on the basis of raising Abadan's output of 100 octane aviation gasoline to some 22,000 barrels per day. Data for assessing the yields by superfractionation of iso-paraffins occurring naturally in Persian crude were amassed from pre-war work carried out on the ultimate constitution of its lighter components. These data were checked in laboratory fractionating columns and then used in the design of large scale fractionating columns.

A further stocktaking of Abadan's capacity to out-turn high octane gasoline was made in 1942, based on squeezing the maximum possible quantity of crude oil through the plant. As a result a further extension was agreed by the PAW which essentially represented additional alkylation/isomerization capacity. This raised the estimated 100 octane production target to 27,000 barrels per day.

A summary of the main items of new equip-

Battery of Superfractionators Including Two 50-Plate Units; Three Divided-Column 100-Plate Units; and A Divided-Column 76-Plate Unit.



Acid Sludge Recovery Unit at Abadan.

ment which were installed during the years 1942-45, for increased aviation gasoline component production is as follows:

9,000 barrels alkylation/isomerization capacity
8,000 barrels SO_2 extraction capacity
85,000 barrels crude oil atmospheric distillation capacity
Four 100-plate superfractionators
Two 76-plate superfractionators
Two 50-plate superfractionators
180 tons/day sulphuric acid manufacturing capacity
240 tons/day acid recovery equipment
3,000,000 lbs. steam generating plant
16,000,000 Imp. gallons/hour of water-cooling tower capacity
Miscellaneous acid treatment and rerun unit capacity

Contracts for most of the above plant and equipment, with the exception of steam generating capacity, were placed in the United States, bringing Anglo-Iranian's eventual expenditure between 1939 and 1945 on American capital equipment and maintenance supplies to nearly $50,000,000, all being on the basis of cash transactions, with no Lend-lease element.

Abadan's gross annual production figures of high octane aviation gasoline over the past seven years are recorded in the following table.

Year	Barrels/Day
1939	195
1940	1,120
1941	3,440
1942	8,640
1943	11,850
1944	23,400
1945	21,900

Although the expansion of aviation gasoline production was the most spectacular of Abadan's achievements during the war, there were a number of other directions in which plant capacity was specially augmented. Bitumen production may be cited as a typical instance. In 1939 the output of solid and cutback grades was 600 barrels per day; by the end of the war the output had risen to the figure of 4,200 barrels per day, supported by four parallel lines of drum-making machines with a total output of over 2,000 drums per eight hour shift.

By way of recording the output of the main products from Abadan through the war years, Table I is given below for ready reference purposes.

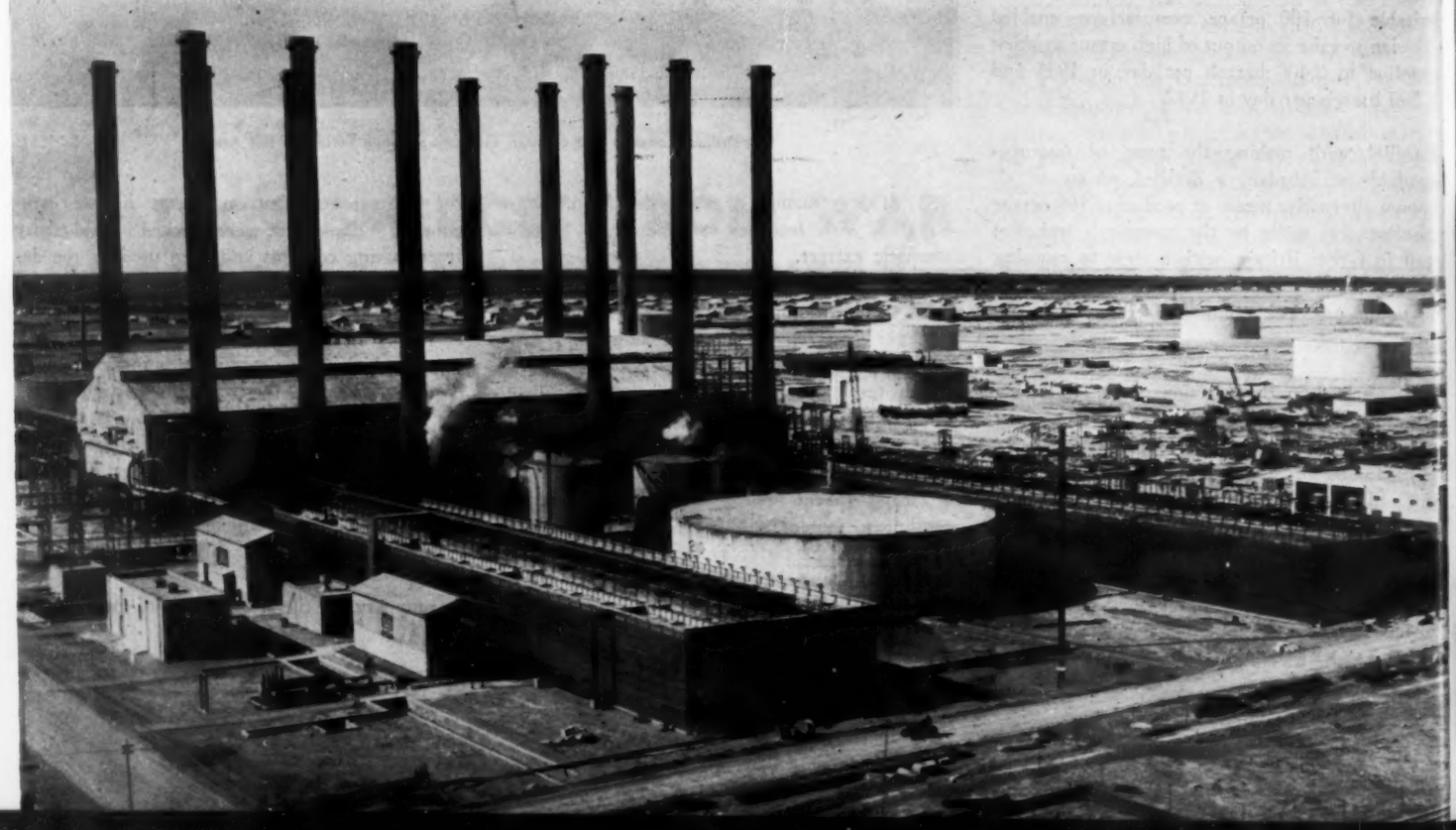
The wartime development of Abadan had to be undertaken at a time when aid-to-Russia and other large scale projects of the Allies in Iran and other parts of the Middle East were simul-

Table I

Average Output of Products—Barrels/Day

Year	Aviation & Motor Gasolines	Kerosene Vaporising Oil & White Spirit	Light Diesel Fuels	Residue Fuel Oils	Bitumen	Total
1939	49,500	13,400	40,400	71,600	600	175,500
1940	24,200	16,800	32,300	79,400	900	153,600
1941	23,700	7,900	24,100	57,000	1,500	114,200
1942	37,400	14,900	44,800	76,400	2,000	175,500
1943	50,800	15,500	39,700	72,500	2,000	180,500
1944	72,500	18,400	50,000	108,000	3,800	252,700
1945	79,600	24,900	61,500	151,000	3,100	320,100

Boiler House and Cooling Towers Installed During the War in Connection With the Aviation Gasoline Program.



taneously calling for manpower and material far exceeding local resources, and when home sources of supply were almost equally short and difficult of access. Quite apart from new construction, even to maintain in working order over five years a refinery of Abadan's size, thousands of miles from its usual sources of engineering supplies, presented a problem of some magnitude in itself. Much improvisation was called for and very considerable effort had to be devoted to the local manufacture of plant spares which normally would have been imported. Some typical data covering workshop expansion between 1941 and 1945 are given below:

	1941	1945
Foundry work	247 tons	439 tons
Machine tools in operation	193	331
Valves re-conditioned	1,600	4,312

More general data covering the same period are as follows:

	1941	1945
General tonnage handled in the refinery	411,000 tons	1,800,000 tons
Construction staff & labor strength	1,920	7,690
Tonnage of food distributed on ration control system	Nil	30,000 tons

The ration control system, mentioned in the last item above, was a novel ancillary service which had to be undertaken by the company owing to wartime interruption of normal local food supplies and distribution. This involved setting up a rationing and supply system for employes and their dependents, some 170,000 in all, in the refinery and fields areas. After a preliminary census, ration cards were issued covering such commodities as flour (for which 24 mills had to be erected), tea, sugar, rice, soap, clothing and so forth. A fishing fleet was organized with a catch averaging some 700 tons yearly during the last three war years, and vegetable and dairy farms were developed. As well as various issuing depots, more than 20 shops were started for the use of employes, selling commodities at prices in many cases kept low by subsidies to ensure a reasonable cost of living. This organization, whose cost including subsidies approximated $4,000,000 for 1945, must be kept in being until the world food position improves.

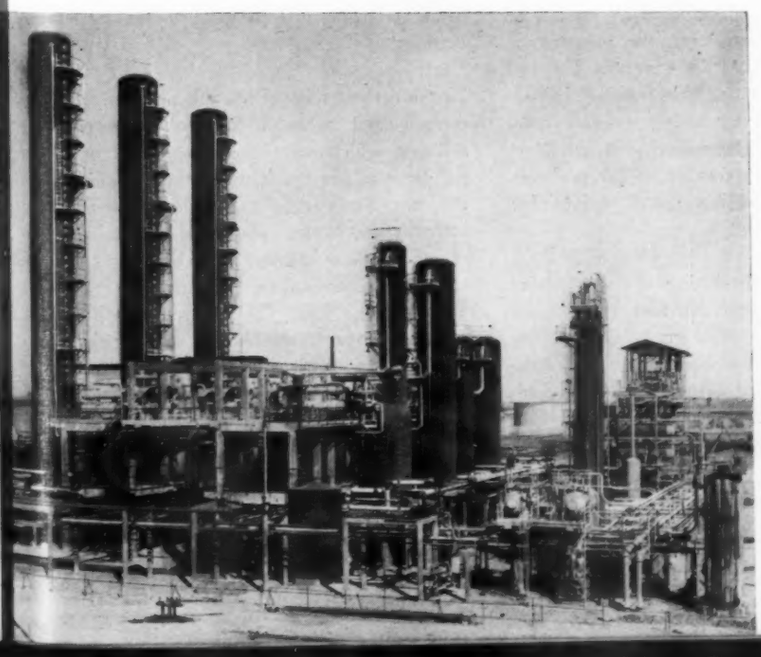
Map Showing Oil Fields and Pipelines Serving the Abadan Plant.

As already stated most of the new refinery equipment installed during the war had to be procured from the United States, and the wholehearted cooperation of both American governmental agencies and contractors in supplying equipment and personnel for construction and supervising plant extensions, largely contributed to the punctual fulfillment of the scheduled expansion program laid down by the Allied control authorities for the refinery.

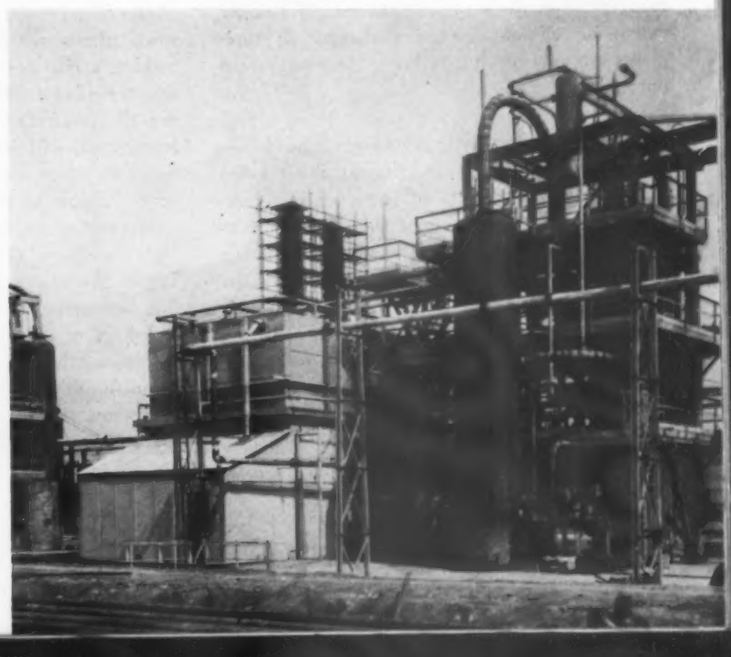
Parallel with this expansion, supporting developments in the oil fields areas (see map) had to run abreast of refinery demands. New fields were brought into production at Gach Saran in 1941, Agha Jari in 1944 and White Oil Springs in 1945, though the senior fields at Masjid-i-Suleiman and Haft Kel were still the largest contributors to Anglo-Iranian's record crude production figure of 354,000 barrels per day in 1945. This compares with a pre-war high of 214,000 barrels per day in 1938 and a wartime low of 139,000 barrels per day in 1941.

Developments on this scale put a heavy strain on the auxiliary services such as housing, health, education and the various public utilities provided by the company in its working areas. Of its 55,000 employes in Persia 35,000 work in the Abadan area and with their families and dependents comprise a township of some 100,000 souls. Inevitably during the war years these auxiliary services, though they were maintained at a high standard, had to take second place to the more primary tasks of construction and production. But their enlargement to make up for wartime leeway is now being rapidly pressed forward while the refinery itself is dealing with the problems of readjustment to normal peacetime development.

Six Thousand Barrel Alkylation Unit.

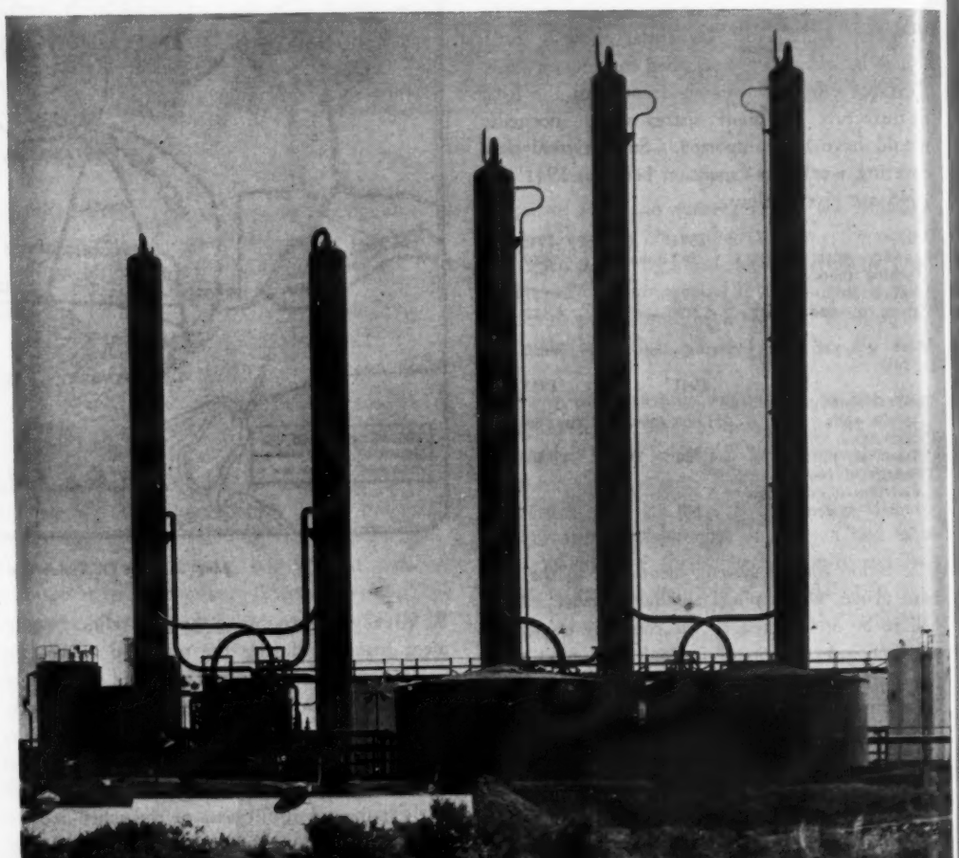


Rerun Stills for Aviation Gasoline Components.



WORLD REFINERY CONSTRUCTION ENTERS NEW STAGE OF EXPANSION

BECAUSE of the tremendous building program carried out during the war years to provide facilities for the production of petroleum products for use of the United Nations there was an assumption that refinery construction in the United States would decline to less than average proportions in the years immediately following the termination of hostilities. To the contrary projects initiated or under way in the current year involve the expenditure of $250 million to $300 million or nearly double the capital investment in the years directly preceding the war. The rate of obsolesence in the refining industry always has been high due to the rapid pace of technical progress, the development of new and more efficient methods and equipment and the frequent introduction of new processes. Due to these conditions and the highly competitive nature of the business it was necessary for operators to adopt improvements as they came along in order to maintain their position in the market. As a result the entire refining plant of the country was renewed every eight to ten years.



Part of a Battery of Superfractionators at the Avon, California, Refinery of Tide Water-Associated Oil Co.

While the expansion of facilities during the war years represented an expenditure of roundly a thousand million dollars by private capital and the government it was directed mainly to multiplying the output of products for military use. A great part of it went into the erection of huge and expensive plants for the production of high octane gasoline, installations to supply butadiene for the making of synthetic rubber and others for the provision of materials entering into the manufacture of explosives. Unavailability of materials and labor interrupted the normal course of construction for the provision of peacetime products and many companies were compelled to postpone plans for expansion that had been drawn up in order to concentrate on meeting military requirements. As a consequence a large backlog of construction orders accumulated which are now being placed and refiners who participated in the war program only to a minor extent or without extensive changes in their plants are now moving to bring their equipment up to date.

Development of catalytic cracking, tremendously stimulated by the war, is bringing about something of a revolution in refinery operation comparable to the introduction of the original cracking process which effected a sweeping change in methods following World War I. The earlier catalytic cracking plants and those built during the war were in large units costly to construct and it was considered that the process was not applicable to runs of less than 20,000 barrels daily which put it beyond the reach of the majority of refiners. Since the close of the war, however, the various catalytic processes have been adapted to economical operation in units of much smaller size with daily runs as low as 2,000 barrels or less. Since 80 percent of the refineries in the United States have a daily throughput less than the 20,000-barrel minimum formerly set for catalytic units it will be seen that a very large field has been opened for this advanced type of cracking and many owners of small plants are investigating the question of making a change-over. It is generally believed that the advantages of catalytic refining, including the possibility of extracting gasoline from lower cuts, will lead the majority of small refiners to adopt one or another of the processes now available as the only means of maintaining a competitive position.

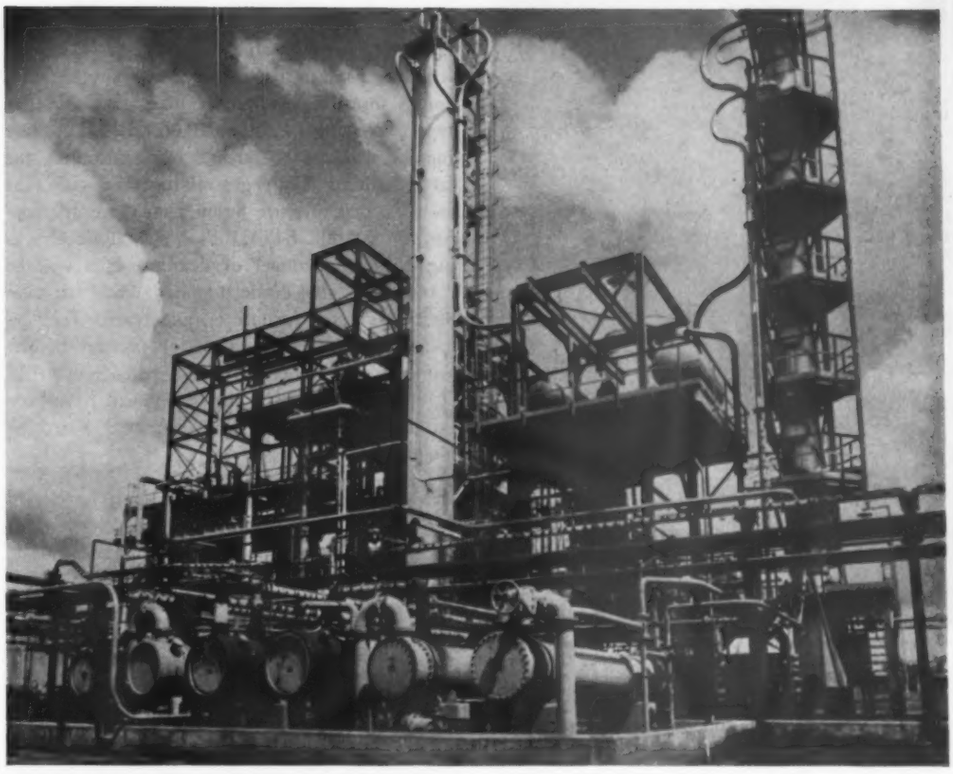
While the plants built during the war period for the production of aviation fuel are now engaged in turning out high grade gasoline for motor cars the prospect of a greatly increased demand for this quality of automobile fuel is leading many of the large oil companies to enlarge their capacity for such production and to construct new plants at points which they consider advantageous for its distribution. Considerable attention also is being paid to the construction of asphalt plants to supply materials needed for the great program of road improvement now shaping up in all parts of the country. Another line of construction activity that is assuming importance is provided by the growing penetration of oil companies into the field of chemical manufacture.

In the earliest days of the oil industry refineries were located in the oil fields of Western Pennsylvania which were the sole source of crude supply or in nearby cities such as Buffalo, Cleveland and Pittsburgh. When the era of pipe line construction began, plants of larger capacity served by these carriers were built on the eastern seaboard around the ports of New York and Philadelphia. Later as the sources of supply moved westward the trend of refining shifted in that direction with a preference for locations in the big cities of the central states. Subsequently, the discoveries in Oklahoma, Texas and Louisi-

ana brought a further shift to the Mid-Continent and Gulf Coast. In 1941 roundly 35 percent of the crude capacity of the 420 refineries then in active operation was concentrated in the Gulf Coast area while 26 percent was in the central states, 18 percent was on the Pacific Coast and 17 percent in the eastern area. During the war the concentration of refining activity in the Gulf Coast district was heightened by the erection of a number of plants of large capacity.

A departure from the westward trend was recorded, however, with the announcement in June by the Texas Company that it had selected Philadelphia as the location of a great new refinery on which work will shortly begin. Details of the plant have not been made public but it will occupy an extensive tract of 1368 acres near the Philadelphia Navy Yard on the Delaware River and will be a multi-million dollar undertaking. One of the reasons adduced for selecting this site is that it is a convenient point for the receipt of crude shipments by water routes from the Gulf Coast, from South America or from other regions overseas. This is interpreted as reflecting an expectation that the United States will import oil in increasing quantities in the years ahead and as suggesting the possibility, in view of The Texas Company's extensive interests in the Middle East, that oil from that area may figure among such imports.

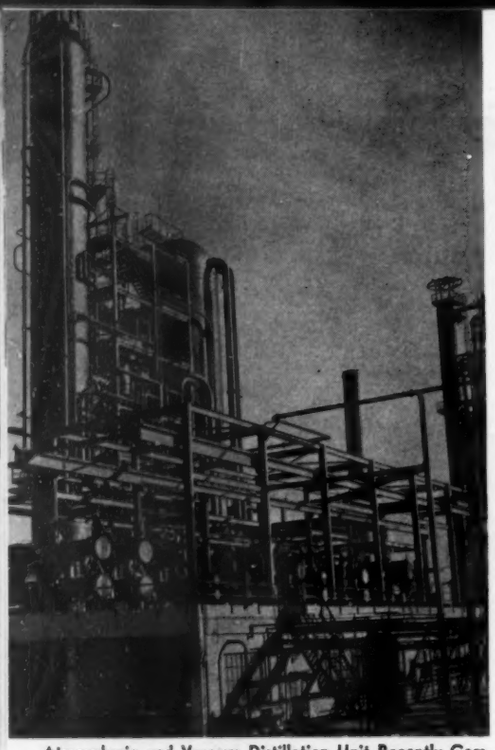
Among other noteworthy additions to refining facilities in the Philadelphia area is the big addition to Gulf Refining Company's plant now nearing completion and the propane deasphalting plant of Atlantic Refining Company with a charging capacity of 4300 barrels daily. Other additions to the company's lubricating oil processing and microcrystaline wax manufacturing installations will include an MEK dewaxing and deoiling unit of 3850 barrels daily capacity and a solvent extraction plant to handle 2400 barrels daily. Sinclair Refining Company is adding a fluid catalytic cracking unit to its refinery at Marcus Hook.



Distillation Unit at Creole Petroleum Corp. Refinery at Carapito, Venezuela. Creole Now is Planning a New $65 Millions Refinery in Venezuela.

Some of the large oil companies that engaged heavily in plant construction in the war period intend to direct their attention during the next year or two to readjustment of existing facilities and to enlargement of their productive capacity rather than to extensive construction of new plants. President Holman of Standard Oil Company (N.J.) told stockholders at their annual meeting in May that capital expenditures, perhaps the largest in the company's history, would be made during the ensuing two years if necessary materials were available. Primary consideration is being given to readjustment from all-out production for war to large volume operations in peacetime manufacture. Capacities will be increased through the removal of bottlenecks and the revision of processes to take advantage of the most recent improvements. Changes already made have enabled three of the company's refineries greatly to exceed their original capacity and fluid catalytic cracking units have attained 180 percent of their designed throughput. Steps

Construction Scene at Houston Refinery of Shell Oil Co. Where a Cat Cracker is Being Installed as Part of a Major Building Program.



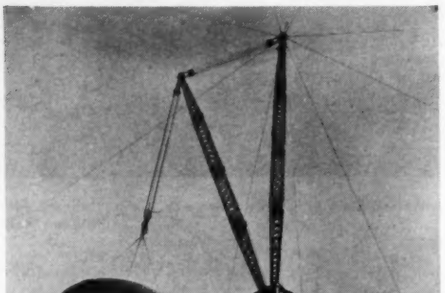
Atmospheric and Vacuum Distillation Unit Recently Completed at an Eastern Refinery by The Lummus Company. Unit Was Designed to Process High Sulphur Crude.

to increase efficiency and to meet changes in product demand will be taken in all the company's plants. Production of Butyl rubber which reached 55,000 tons in 1945 is to be raised to 68,000 tons in the current year.

Important additions are being made to refining facilities in the area centering about Chicago and at other points in the Central States. It was recently announced by President W. Alton Jones that as soon as conditions permitted Cities Service Company would begin work on the expansion of its East Chicago refinery as part of a $50,000,000 program of capital expenditure. Featured in this program will be a fluid catalytic unit of the latest type which will increase the daily throughput of the refinery to 35,000 barrels. Completion of this unit in addition to the three which Cities Service has in operation at its great Lake Charles, La., plant will make the company one of the largest users of this type of equipment in the world. The installation, from design to construction, will be under the supervision of the M. W. Kellogg Company. Other new equipment to be installed at East Chicago will include a feed preparation unit, a polymerization plant, gas recovery equipment, additional tankage for crude oil and finished products, increased steam generating capacity, an enlarged laboratory, pump house and change house facilities. The work is expected to reach completion in the spring of 1948. Construction activities of Sinclair Refining Company at East Chicago include a fluid catalytic cracking plant and a lubricating oil installation comprising solvent refining, solvent dewaxing and propane deasphalting units. A detailed description of the three catalytic cracking units now under construction for Standard Oil Company (Indiana) appears on other pages of this issue.

In order to meet expected volume increases of various refinery products and increases in octanes of motor gasoline, The Texas Company is now expanding its Casper, Wyoming, refinery and is installing equipment necessary for latest type processing. A new 10,000 BPOD crude topping and vacuum unit is being installed, the latter unit to supply gas oil together with that from normal pressure flashing on the crude topper for a 4,000 BPOD Fluid Catalytic Cracking Unit. A number of distillate cuts will be made from the crude topping units to meet diesel, kerosene, furnace oil and tractor fuel demands. Inasmuch as a major portion of the crude processed will be from so-called sour fields, crude unit and all cracking equipment have been suitably designed to meet expected corrosion problems.

Existing thermal equipment is being remodeled to permit increased throughput and reforming of heavy straight run if desired. A new catalytic



Raising Regenerator Skirt at the Whiting, Ind., Cat Cracker Recently Engineered by M. W. Kellogg Company.

polymerization unit is being built to convert light hydrocarbons of the propane-butane boiling range to usable gasoline products. New asphalt converters are being built which will utilize residuum from the vacuum unit as a charge in the making of a full line of surfacing and asphalt materials. The installation is expected to be completed early next year.

A new, standard-size, Fluid Catalytic Cracking unit was placed in operation at The Texas Company's Lockport, Illinois, refinery in January of this year. This unit was a part of the facilities constructed by The Texas Company in connection with the recent war to permit production of aviation gasoline components as well as additional charge stock for the existing alkylation unit. The fluid unit is currently charging virgin gas oil, producing high octane blending components for inclusion in motor gasoline, the light hydrocarbons from this operation supplementing the light hydrocarbons from thermal operations as alkylation and polymerization unit charge stock.

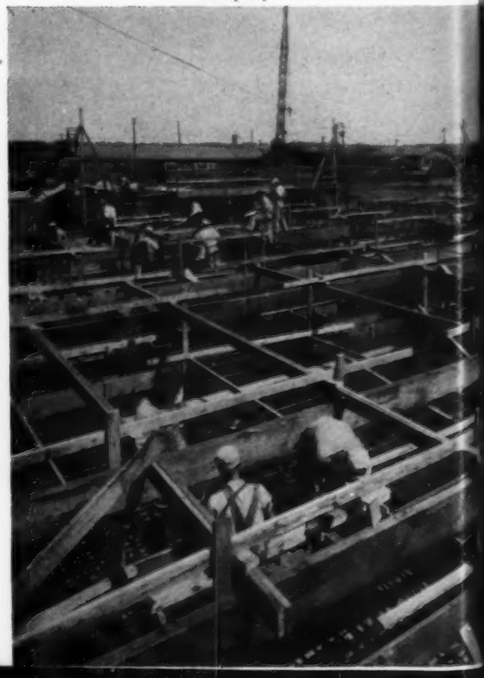
Concurrent with the construction of the Fluid Catalytic Cracking unit, the alkylation facilities at the Lockport refinery were expanded to increase the production of alkylate for inclusion in aviation gasoline. As in the case of the fluid unit, these facilities were also erected as part of the national emergency program for 100 octane aviation gasoline manufacture.

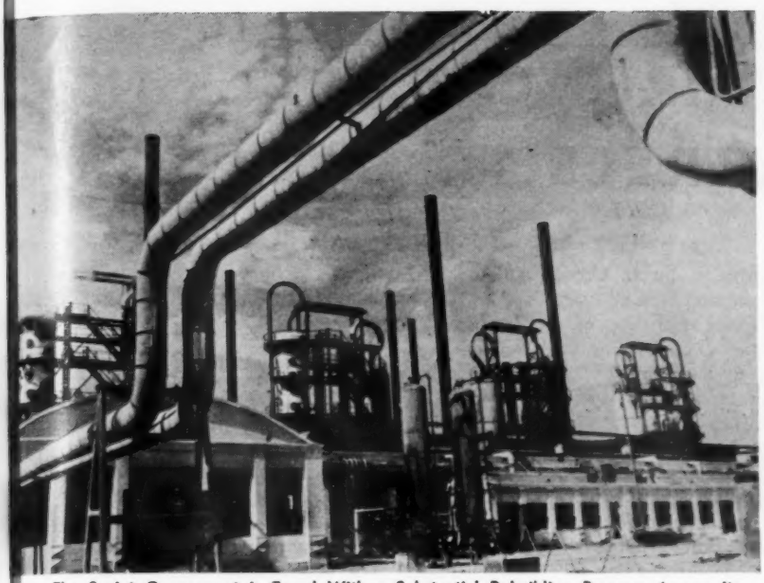
Besides these recent additions to the refinery, the plant is also equipped with hydroforming and polymerization facilities for the production of high octane blending components, as well as the conventional fractionation, thermal cracking and coking equipment. The Lockport refinery has a rated crude capacity of 50,000 barrels per day, and, in addition to producing three grades of motor gasoline, manufactures aviation gasoline, diesel fuel, furnace oils, tractor fuel, fuel oil, coke and surfacing materials.

At Wood River, Illinois, Shell Oil Co. is rounding out the facilities of its great refinery by addition of a vacuum flashing unit with a capacity of 35,000 barrels daily of topped crude to give 28,000 barrels daily of charging stock for the catalytic cracking units previously completed. It is to be built by C. F. Braun Co. at an estimated cost of $1,500,000 and completion is expected in 1947. A novel feature of the plant will be a spheroidal flashing chamber designed to withstand a vacuum of the order of 100 millimeters.

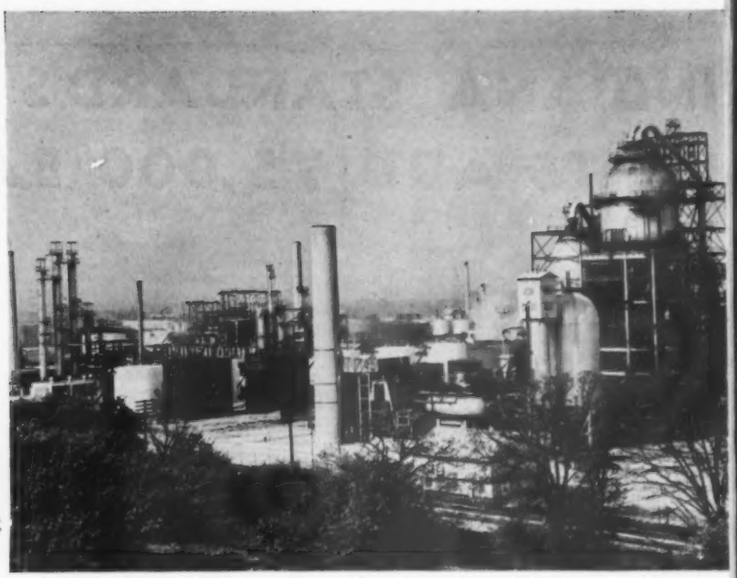
Other construction projected or under way in the central states includes a lubricating oil plant for Stanford of Ohio, a coking unit for Pure Oil Company at Toledo, Ohio, a catalytic cracking plant of 4,000 barrels daily capacity incorporating the fluid process of Universal Oil Products Company for Aurora Gasoline Company of Detroit, Michigan and a TCC plant of 3,000 barrels daily capacity building by the Lummus Company for Leonard Refineries Inc. at Alma, Michigan.

Regenerator Foundation Mat for the Fluid Catylitic Cracking Plant Being Engineered for Standard Oil Co. of Indiana at Sugar Creek, Mo., by The M. W. Kellogg Company.





The Soviet Government is Faced With a Substantial Rebuilding Program Among its Refineries Such as the Above. Sovfoto.



One of the Most Recently Completed Large Fluid Catalytic Cracking Plants is That at the Lockport, Ill., Works of The Texas Company.

In the Gulf Coast area a number of large undertakings are under way. Shell Oil Company is spending $16,000,000 on the expansion of facilities at its Houston, Texas, refinery. Included in this project is the largest fluid catalytic cracking plant in Texas. This unit will process 25,000 or more barrels a day to give high quality automotive fuels and propane-propylene, butane-butylene fractions for chemical synthesis. The plant employs an improved microspheroidal synthetic catalyst, spray-dried by techniques developed by Shell. This catalyst is manufactured by American Cyanamid and Chemical Corporation at Fort Worth. Associated with the cracking unit are high pressure absorption facilities for the recovery of gases used for alkylation and as chemical intermediates. Completion of this plant which will cost $11,000,000 is expected before the end of 1946.

Capacity of the refinery's power generating equipment is being increased from 5,000 to 25,000 kilowatts to meet current and anticipated expansion. The installation consists of two 10,000 KW. Allis-Chalmers non-condensing turbine generators, three Babcock and Wilcox integral furnace boilers, and a 625,000-pound per hour Cochrane hot process line gypsum water heater. Fuel for the boilers will be natural refinery gases, plus a small quantity of refinery fuel oil. Exhaust steam from the turbines at 200 psi will be used to augment refinery process steam. This new equipment is expected to be in operation by early 1947.

A million dollars is being spent at Houston on a research center for Shell's recently organized division of exploration and production research. Here, under one roof, research in physics, chemistry and geology as they are related to petroleum production will be co-ordinated towards the development of new and more efficient methods for discovering oil and for recovering it in maximum quantities from the formation. Now being constructed by the Austin Company, the laboratory will be a two-story air-conditioned building covering 40,000 square feet and will contain, in addition to modern laboratories, a library, conference rooms, an outdoor dining terrace and a cafeteria for 75 persons. Designed to accommodate the staff of 130, the laboratory can be expanded to take care of 150.

Not included in the above estimate is the new lubricating oil manufacturing plant which will be built adjacent to the present refinery on the Houston ship canal. It will cover 75 acres in the 650-acre tract purchased last year to provide for postwar expansion. This new installation will consist of five separate plants of the latest design, embodying improvements developed to meet wartime needs or resulting from wartime research. Included in the installation will be plants for vacuum distillation, deasphalting, solvent extraction, dewaxing and chemical treatment. The new refining units when finished will be able to completely process high, medium and low viscosity index lubricating oils from southwest crudes. In addition to the processing equipment, at least 10 separate buildings will be required to house various auxiliary facilities of the new plant and additional outside equipment will include storage tanks and loading facilities.

(Continued on page 104)

General View of General Petroleum Corporation's Torrance, Calif., Refinery Taken from Top of TCC Catalytic Cracking Tower.

Three 800-hp Gas Engines Driving Electric Generators at Shell Oil Company's New Sheridan, Texas, Cycling Plant.

INDIANA STANDARD'S THREE CAT CRACKING UNITS ADD 75,000 BARRELS TO CAPACITY

NEARING completion at the Whiting, Indiana, refinery of Standard Oil Company (Indiana) is the first of three new fluid catalytic cracking units now in various stages of construction at Whiting and at Sugar Creek, Missouri. When completed these three large units will each be capable of processing 25,000 B/SD of gas oil charge giving a total combined capacity of 75,000 B/SD. With the first of the two Whiting units scheduled to be in operation late this summer, current plans call for completion of the Sugar Creek unit and the second Whiting unit early in 1947.

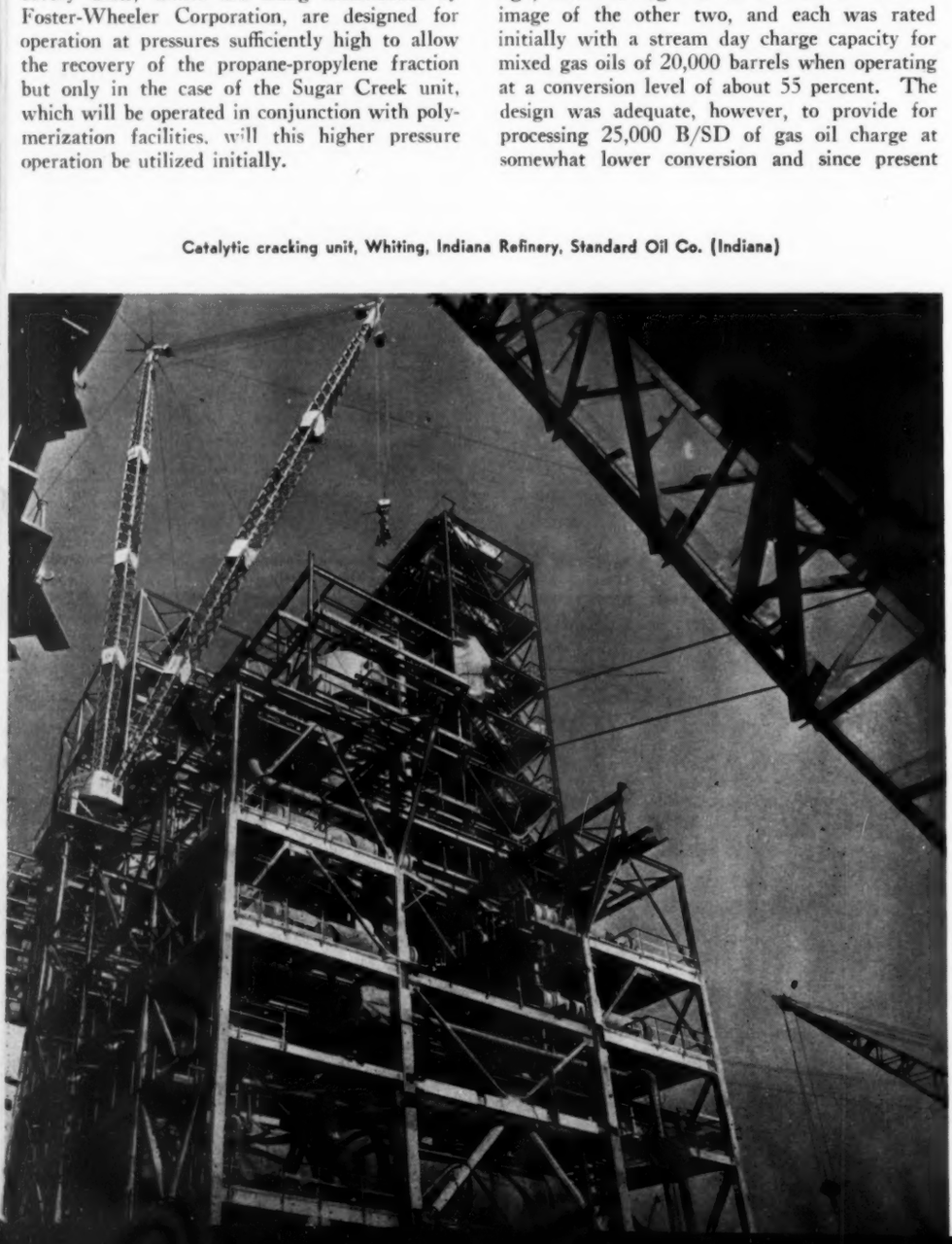
In conjunction with each of the catalytic cracking units, but not as an integral part thereof, is being constructed a vapor recovery plant capable of processing the total gas and distillate output of each catalytic cracking unit. The vapor recovery units, which are being constructed by Foster-Wheeler Corporation, are designed for operation at pressures sufficiently high to allow the recovery of the propane-propylene fraction but only in the case of the Sugar Creek unit, which will be operated in conjunction with polymerization facilities, will this higher pressure operation be utilized initially.

Construction of the facilities at Sugar Creek presents an unusual aspect in that lack of space necessitated locating these units at the top of a hill west of the refinery proper. In leveling off this site it was necessary to move more than one million cubic yards of earth before initial construction work could begin. The accompanying photograph shows the high earthen walls remaining to the west and south of the site after excavation had been completed and before construction had progressed to its current stage. When completed these Sugar Creek units will stand out as sentinels above the surrounding territory along the Missouri River and will be visible for miles in all directions.

Each of the three fluid catalytic cracking units which are being constructed by The M. W. Kellogg Company, is based on a common design, with the Sugar Creek unit to be a mirror image of the other two, and each was rated initially with a stream day charge capacity for mixed gas oils of 20,000 barrels when operating at a conversion level of about 55 percent. The design was adequate, however, to provide for processing 25,000 B/SD of gas oil charge at somewhat lower conversion and since present plans call for operation under the latter conditions, the 25,000 B/SD capacity figures become realistic. Considerable flexibility will exist in cracking severity to be maintained and in the yields which will result therefrom.

A preheating furnace has been provided to bring the charge to an initial temperature of about 750°F. Reactor temperature will be maintained at about 910°F. while maintaining a 6.8-to-1 catalyst to oil ratio. Two stages of cyclones will be employed in the reactor and three in the regenerator. The bubble tower will operate at about 9 psig (pounds per square-inch gauge) and produce overhead gas and unstabilized gasoline products which will be sent to the vapor recovery unit, and side stream products of light gas oil and heavy gas oil. The bubble tower bottoms will pass to a slurry settler from which decanted oil and slurry recycle will be withdrawn. Spent catalyst will be carried by a portion of the regeneration air into the bottom of the regenerator which will operate at about 1925°F. and 10 psig pressure. Recycle catalyst cooling will be employed to control the regenerator temperature. The coke burning capacity of each unit will be in excess of 16,000 pounds per hour with regeneration air being supplied by a 5,400 H.P. Ingersoll-Rand compressor discharging 3,030,000 cu. ft. per hour of air from its fourth stage at a pressure of 27 psig.

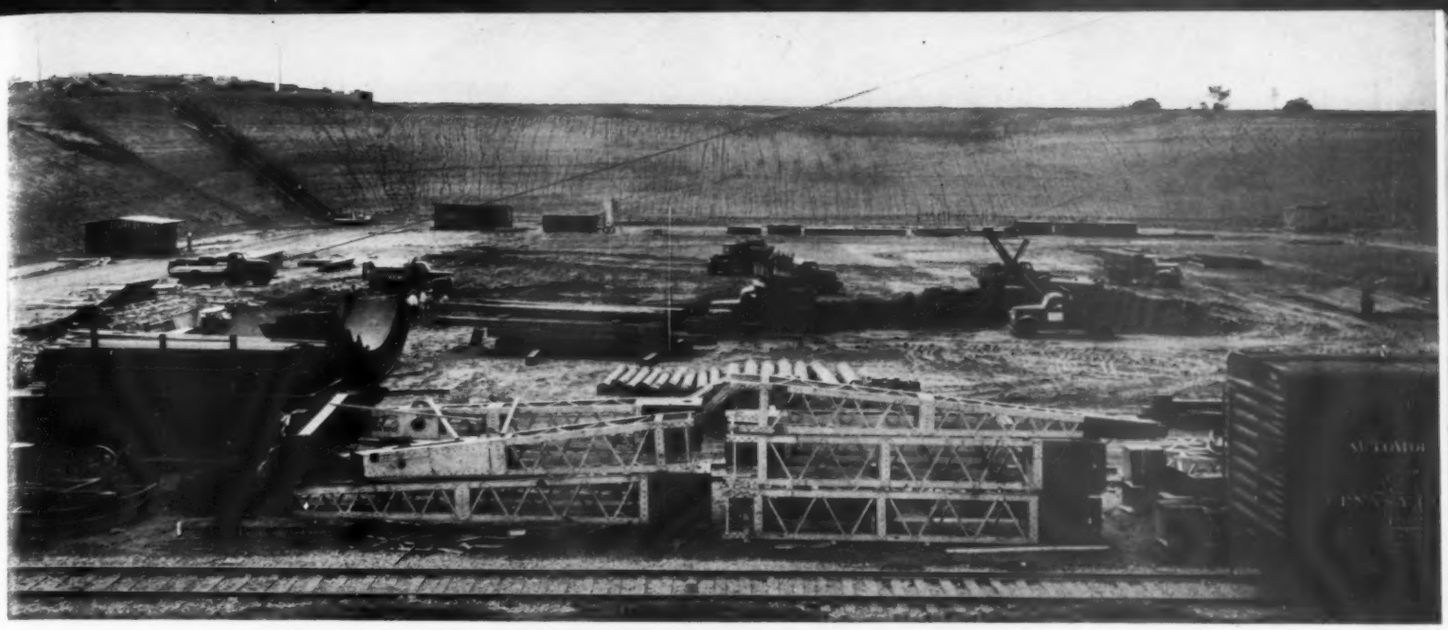
Catalytic cracking unit, Whiting, Indiana Refinery, Standard Oil Co. (Indiana)



Because these catalytic cracking units were designed for processing high sulfur West Texas stocks generous provision has been made for alloy protection against corrosion at all critical points. Pluramelt carrier lines have been utilized where indicated and Pluramelt cladding has been provided for protection of the reactor. The fractionator tower is to be equipped with 18 pressed steel fractionating trays and eight baffles and is lined with a 7/64 in. thick stainless steel liner spot-welded to the entire interior of the vessel.

The 22′6″ x 50′0″ reactor and the 37′10″ x 40′0″ regenerator were welded in the field from shop fabricated sections. All welds were completely x-rayed for the detection of any flaws, and this job alone represents a tremendous task for vessels of this size. Each vessel is to be completely stress relieved on completion and prior to being placed in initial service. The 16′2″ x 108′ long fractionator now in place on the first Whiting unit was fabricated in the Milwaukee shops of the A. O. Smith Corporation and represents one of the largest shop-fabricated vessels ever shipped to a refinery. Transportation of this vessel by rail and barge presented a real problem but delivery was completed on schedule and without incident.

In designing these catalytic cracking units and vapor recovery units, all possible advantage was taken of experience gained from construction and



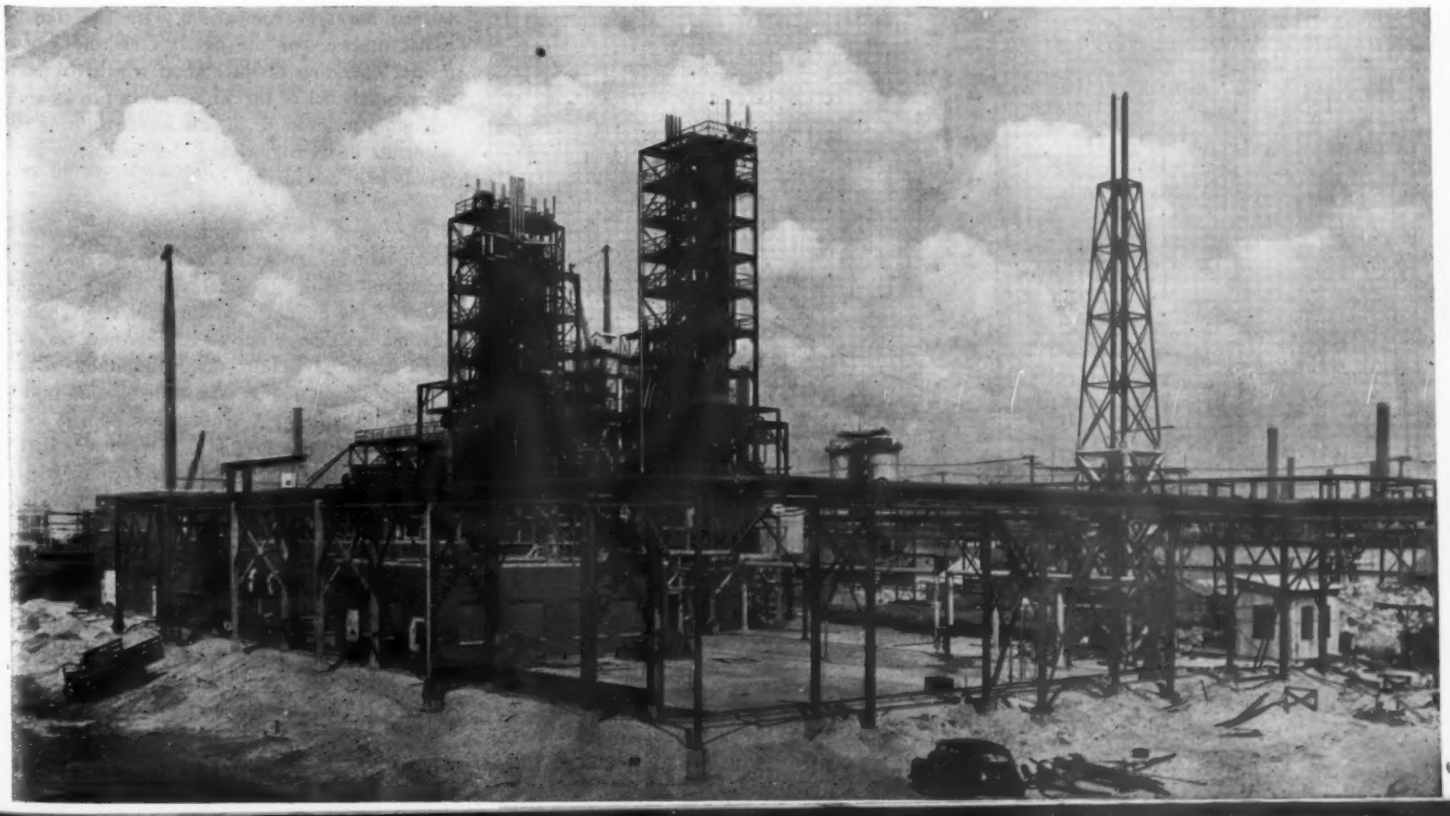
More than 1,000,000 cubic yards of earth was moved in preparing site for the Sugar Creek Mo. refinery.

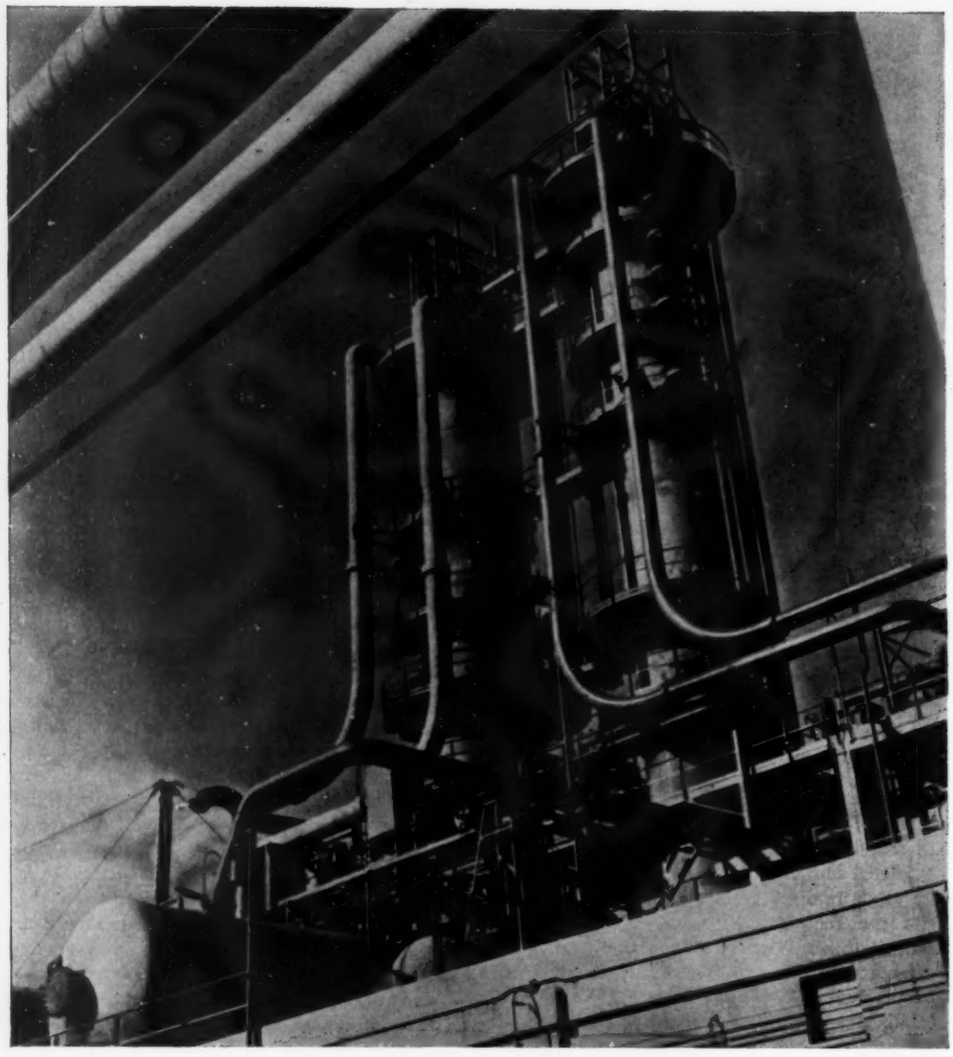
operation of the wartime units. Many hours were spent by the designing engineers to assure greatest accessibility, convenience, economy, practicability and safety of each item of equipment. To assure ready and rapid access for the operators to the higher levels of the unit, which is equivalent to a 16-story building in height, a high speed passenger elevator is being provided. In addition a second elevator is also being provided for the use of the mechanical crafts in transporting materials and equipment readily. From the standpoint of safety each set of units is being provided with adequate blowdown systems and flares capable of handling rapid and safe elimination of hydrocarbons from any or all sections of the units in case of emergency requirements. Physical layout of equipment has been established in such a way as to meet exacting requirements for simplifying to the greatest extent possible the pattern of the numerous air, catalyst, oil and auxiliary pipe lines. To aid further in identification a standard color scheme has been adopted which will allow lines for any particular service to be readily distinguished. This feature has proved its worth in other installations operated over a period of years.

At Whiting, each vapor recovery unit can be converted to recover propane and propylene if desired, but this type of operation is not contemplated initially at Whiting. In operation of the vapor recovery units liquid and vapor products from the catalytic cracking units are to be charged to an absorber tower fitted with a reboiler and stripping section. This absorber will be operated at 75 psig pressure and will employ stabilized heavy naphtha as lean oil. Rich oil will be denuded in a lean oil still which will be operated at 90 psig pressure. Part of the lean oil bottoms stream will be recycled to the absorber and the net production of stabilized heavy naphtha will be withdrawn to storage. Overhead from the still will be completely condensed and charged to the stabilizer tower, which will operate at 295 psig pressure. Dry gas will be eliminated overhead from the stabilizer and stabilized light catalytic naphtha will be withdrawn from the base. The vapor recovery units will be operated to obtain about 95 percent butane recovery.

So as to provide adequately trained personnel for operation of these new units an intensive training program has been underway for some time. Operating crews have already become thoroughly acquainted with the details of the first completed vapor recovery unit at Whiting and are currently engaged in study of the catalytic cracking unit so that no delay will be caused in bringing the first of these new units on stream.

Vapor Recovery unit at Whiting, Indiana refinery.





Side view of 99 and 113-foot fractionating columns.

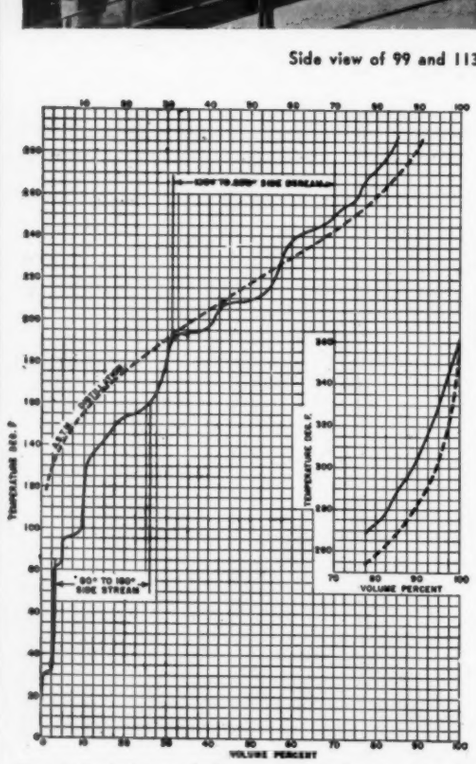


Fig. 1. Typical true boiling point distillation of crude naphtha.

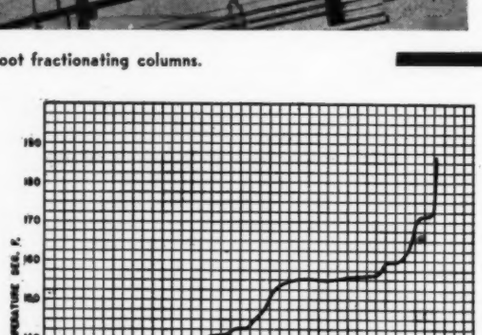


Fig. 3. True boiling point distillation of first side stream.

By John F. Middleton*

NAPHTHA

THE entry of the United States into World War II created immediate demands for types of petroleum products that could be produced most advantageously by processes that were then either still in a stage of development or that had only recently been placed in operation on a commercial scale. The fulfillment of these sudden demands required the rapid construction of many plants which were new to the industry and imposed on the fabricators of petroleum refining equipment the burden of adapting their chemical engineering designs to purposes which then seemed novel by comparison with the conventional practices of the day. Thus the fundamental operation of distillation which has been an essential tool of the oil business since its very beginning was applied in new ways requiring refinements in its engineering that had never previously been considered.

The terms "superfractionation" or "precise fractionation" are well-known in the technical literature, and imply practically complete separation of the desired products from a given distillation. Although not an entirely new concept of the petroleum industry at the beginning of the war, application of that type of distillation to the separation of the light hydrocarbon isomers used as feed in processes supplying war-needs drew attention to the difficulty of the chemical engineering problems involved and particularly to the

* Design Engineer, Petroleum Refinery Division, Foster Wheeler Corporation.

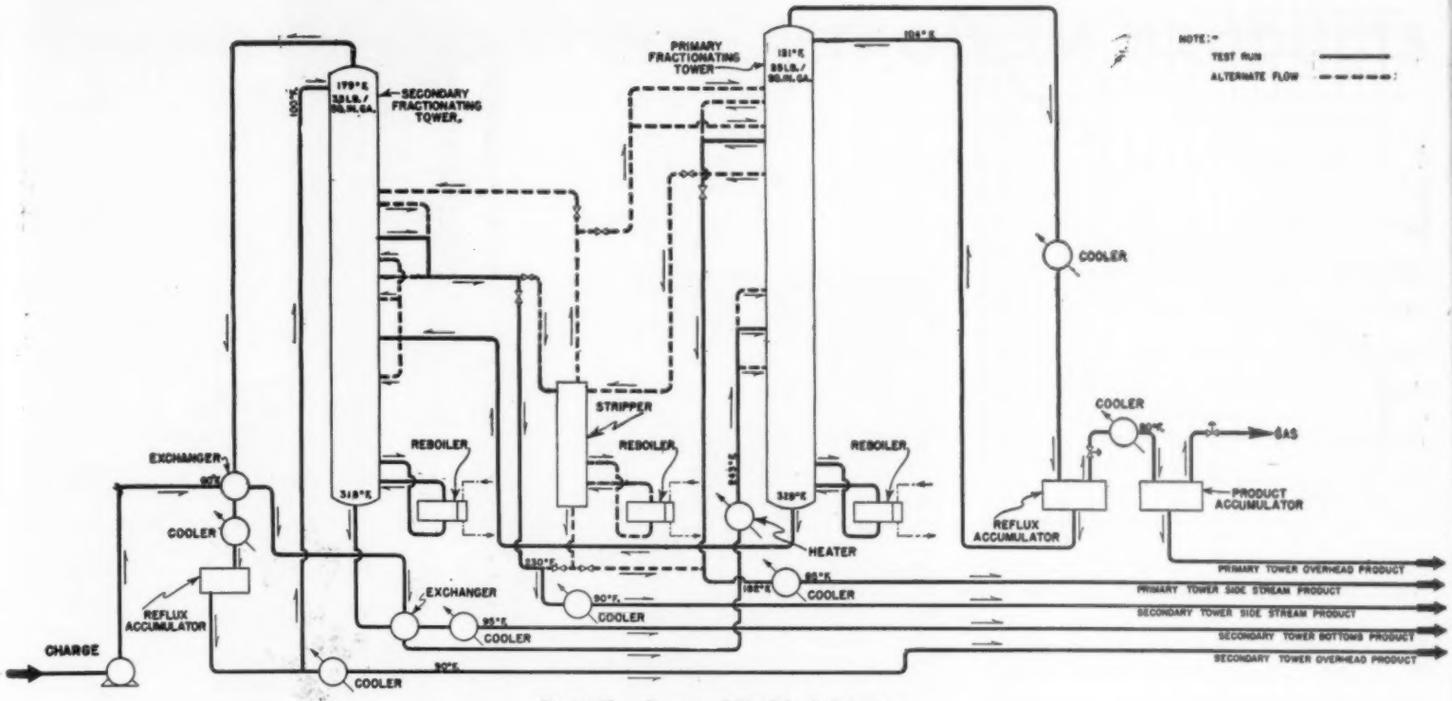


Fig. 2. Flow diagram of Naphtha fractionator.

FRACTIONATOR FOR FEED PREPARATION

extraordinary height of the columns required to make such separations.

"Precise fractionation," however, is only one of many ways in which the distillation operation was applied to the preparation of feed for the various processes used in the manufacture of military petroleum products. Although the general purpose of "feed preparation" was always to produce a mixture of hydrocarbons containing a concentration of the essential components high enough to give optimum results in the operation of the subsequent process, the degree of separation required for each feed stock varied considerably from one process to another. At one extreme the feeds consisted of the almost pure desired hydrocarbon with only a minimum of contamination and were, therefore, made by the "precise fractionation" already mentioned.

At the other extremely wide boiling range mixtures were adequate, such as gas oil separated from reduced crude for feed to catalysic or thermal cracking operations. The case to be discussed here is intermediate between these two extremes, since the two hydrocarbon mixtures that the plant was to separate from a crude naphtha charge had fairly narrow boiling ranges, but their concentrations in the finished feed stocks were not required to exceed 80 to 85 per cent. The type of separation involved is well-known to technologists as "sloppy fractionation."

The degree of separation required in the present problem has frequently been used in naphtha re-run units where the aim has usually been to achieve a specified, rather wide A. S. T. M. boiling range product as an overhead stream. However, the design of naphtha re-run distillation equipment is a comparatively simple matter based largely on empirical considerations, established by operating experience. By contrast, the two products of the feed preparation unit discussed here had to be produced as heart cuts and in addition were rigidly specified by true boiling point distillation analyses whose maximum limits of contamination were required to be guaranteed by the contractor. These requirements, coupled with the complete absence of any operating precedents, make the design of this type of feed preparation plant the most difficult of all problems in multicomponent fractionation, since none of the short-cuts that simplify the approach to the "precise fractionation" design, nor any of the empirical considerations employed in re-run column design, can be employed.

The war-expansion program of a leading mid-western refiner included two plants requiring definitely specified, but not sharply separated feeds. One required a feed consisting mainly of pentanes and hexanes separated from virgin crude naphtha, and the other required, principally, a mixture of heptanes and octanes which could also be made from the same naptha. The availability of adequate concentrations of the hydrocarbons needed for both feed stocks in the same crude naphtha indicated that a single distillation plant would suffice to prepare both. The problem of designing and building this feed preparation plant was assigned to the Petroleum Refinery Division of the Foster Wheeler Corporation.

In terms of a true boiling point distillation of the crude naphtha from which they were obtained, the first of the feed-stocks boiled mainly between 80 and 160 deg. F., while the second one came off principally between 190 and 250 deg. F. A typical T. B. P. distillation of the crude naphtha is shown in Fig. 1, from which it may be seen that a continuously operating distillation plant producing cuts of the two desired boiling ranges must separate the naphtha charge into five separate streams. For their respective boiling ranges, and the separations intended, these streams were expected to have essentially the constituents listed in Table I.

If close fractionation and maximum yields for the two-feed-stocks had been required, four fairly tall towers would have been needed to separate the five streams, and since there would then have been no overlapping or components between any two adjacent streams, the process design problem would have been much simpler.

Actually, although some small advantage in the operation of the catalytic processes following the feed preparation unit might have resulted from such close fractionation, this would not have been sufficient to justify the greater cost of the equipment required to achieve it. Instead, the preliminary economic study of the project resulted in the decision to use only two bubble tray columns in the plant and consequently the

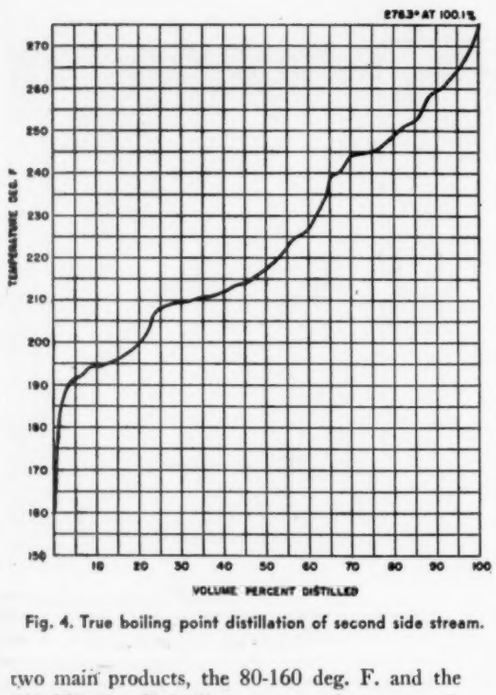


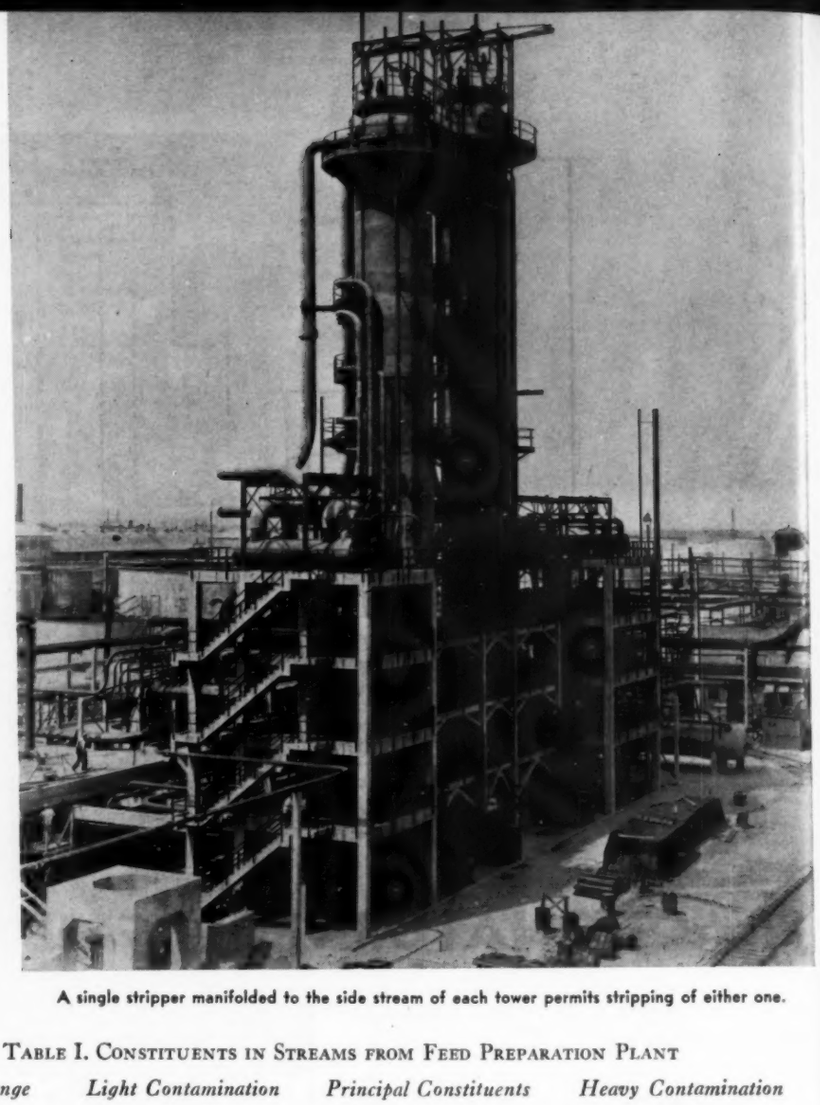
Fig. 4. True boiling point distillation of second side stream.

two main products, the 80-160 deg. F. and the 190-250 deg. F. boiling ranges, whose compositions were the controlling factors in its design, had perforce to be removed as side-streams.

As implied before, the main difficulty in carrying out the process engineering for this type of feed preparation plant, is the estimation of the compositions of the products to assure that their guaranteed limits of contamination are not exceeded, but once this difficulty has been overcome the design is more or less conventional. In the present case, the final design resulted in two fractionating columns, each of 11½ ft. diameter, the first being 113 feet tall and the second 99 feet tall. One unusual feature of the design is a single stripper manifolded to the side stream of each tower to permit stripping of either one. The stripper was added for the purpose of controlling the vapor pressure of the first tower's side stream in case it were desired to use that stream as an aviation fuel base, or alternately it might be used to strip the second tower's side stream and thereby increase slightly its concentration of heptanes and octanes. The schematic flow sheet for this plant is presented in Fig. 2, and shows the operating pressures and tower temperatures.

After the "feed preparation" plant had been on stream for six days, a ten day acceptance test-run was started to demonstrate the unit's ability to separate the desired products at the guaranteed rates and compositions. The results of this test-run, compared with the guarantees made for the corresponding items, are tabulated in Table II, and the compositions of the two side streams produced are shown in the true boiling point distillation curves given in Figures 3 and 4.

This test was completed successfully at the first trial without any adjustments to the equipment specified by the design, and without exceeding the guaranteed consumption of utilities.



A single stripper manifolded to the side stream of each tower permits stripping of either one.

TABLE I. CONSTITUENTS IN STREAMS FROM FEED PREPARATION PLANT

Boiling Range	*Light Contamination*	*Principal Constituents*	*Heavy Contamination*
Up to 80 deg. F.		n-Butane	iso and n-Pentane
80 to 160 deg. F.	n-Butane	Pentanes and Hexanes	Methylcyclopentane, Cyclohexane and i-Heptane
160 to 190 deg. F.	Hexanes	Methylcyclopentane and Cyclohexane	Heptanes
190 to 250 deg. F.	n-Hexane, Methylcyclopentane and Cyclohexane	Heptanes and Octanes boiling up to 250 deg. F.	n-Octane and Nonanes
250 deg. F. and up	n-Heptane and Octanes boiling up to 250 deg. F.	n-Octane, Nonanes and heavier	———

TABLE II. COMPARISON OF GUARANTEES AND PERFORMANCE FOR FEED PREPARATION UNIT

	Guaranteed	*Ten-Day Test Run*
Feed Rate	Not less than 21,000 bbls. per day	21,500 bbls. per day
FIRST TOWER SIDE STREAM		
Recovery of 80-160 deg. F. material in side stream as per cent of charge to plant	No less than 18 per cent	20.7 per cent
C4 and Lighter in side stream	Not more than 3 per cent	1.9 per cent
A. S. T. M. End Point of side stream	Not more than 170 deg. F.	157 deg. F.
SECOND TOWER SIDE STREAM		
Yield of side stream as per cent of charge to plant	Not more than 42 per cent	41.2 per cent
Recovery of 190-250 deg. F. material in side stream as per cent of 190-250 deg. F. material in charge to plant	Not less than 85 per cent	89.7 per cent
Contamination by material boiling below 190 deg. F. as per cent of side stream	Not more than 8.0 per cent	3.4 per cent

NOTE: (1) All percentages on volume basis.
(2) All boiling range recoveries determined by T. B. P. distillation of average samples.

DEMAND FORECAST FOR PETROLEUM PRODUCTS

By A. J. McIntosh
Economist,
Socony Vacuum Oil Company

REFINERS in the United States have experienced a demand for petroleum products during the first part of 1946 much greater in volume than had been anticipated. Part of this extraordinary demand has resulted from industrial activity greater than was forecast and from the exceptionally large continuing requirements of the Navy and War Shipping Administration. So far crude runs to meet these demands have been 20 percent over the 1941 average. For the year 1946 as a whole it is forecast that refiners will find demands sufficient to substantiate runs to stills 17 percent over 1941.

The demand for individual products, however, shows considerable variation. Kerosene and fuel oils are forecast to be 31-25 percent greater than in 1941 while gasoline shows only a four percent increase. These annual rates are in some cases lower than the calculated demands shown during the early months of 1946. The Navy and war shipping requirements have been tentatively shown as declining substantially from present levels. Unsettled conditions in the United States have created abnormal demands for petroleum products and there are indications that some stock building has taken place in bulk plants and consumer inventories which are of a non-recurring nature. The exceptionally high gasoline demand experienced so far seems to be caused by an unseasonably high use during a mild spring with an earlier farm requirement.

Looking ahead to 1950, when we forecast a mild recession in business activity, demand upon domestic refiners for gasoline may be only slightly higher than now but distillate fuel oils needed are forecast to show a further increase by 20 percent. On the other hand the residual demands upon refiners may decline about 20 percent because of somewhat smaller industrial use and larger imports. Over-all requirements upon refiners in 1950 may be no greater or even slightly less than in 1946. During the intermediate years demands show small over-all increases above 1946. These details are shown on Table 14.

Some of the basic assumptions which were made and upon which many of the forecasts are calculated are shown in Table 1. The effect of the change in average price levels, both wholesale and retail, upon currently reported United States figures representing National Product, Payments to Individuals and Disposal Income, are shown in this table. We believe that the Cost of Living indexes must rise considerably during 1946 and 1947, reflecting somewhat similar increases in the wholesale prices and adjustments for increased material and labor costs in distribution. After that prices may decline.

Albert J. McIntosh, economist, Socony-Vacuum Oil Company, entered the petroleum industry in 1912, at the age of 14 and has been associated with one company for 34 years. First employed as an office boy, he completed his high school and college education by attending night school.

In 1917, Mr. McIntosh was given leave by the company to work in the petroleum division of the Fuel Administration. The following year, he entered the Army and served in the coast artillery. Upon his return to the company, he enrolled in New York University and was graduated in 1923 with a Bachelor of Commercial Science, cum laude.

During the NRA days, Mr. McIntosh was a member of the Statistical Committee of Planning and Coorodination Committee. During World War II, he was a member of the Petroleum Economics Sub-Committee of the Petroleum Industry War Council and served as chairman of the East Coast Fuel Oil Advisory Committee of the OPA.

Author of several papers for the American Institute of Mining and Metallurgical Engineering, Mr. McIntosh has also been active in the American Petroleum Institute and is serving as chairman of its Statistical Advisory Committee and as a member of the recently organized Economic Advisory Committee of the Interstate Oil Compact Commission. He is a frequent speaker at technical and trade association meetings.

Industrial production is forecast to be somewhat higher than in 1941 during the coming year and to rise to a peak in 1947 almost as high as it was in 1942 under war conditions. Thereafter we forecast a drop in activity to the 1946 level and further declines for each of the next two years. Currently production or other economic services are not as high as the number of civilians employed would indicate which is another way of saying that labor efficiency is low.

As can be seen from Table No. 1, the general conditions forecast in the postwar period are on an average somewhat better than 1941. During 1946, the earlier part of the year unquestionably will be below the annual average and the latter part of the year may be as high as 1947.

Under the conditions forecast, National Income (net) during 1946 was indicated to be about 45 percent greater than in 1941 and to maintain relatively high levels until sometime during 1949 when we expect that there might be a mild business recession. If this takes place it would result in 1950 National Income being reduced to a level which would be about 15 percent over 1941 but 20 percent less than the current year.

Motor Fuel Consumption

The assumptions as to the numbers of passenger cars in use are shown in Table No. 7. These are predicated upon the registration of 2.5 million new cars in 1946 and an average production of over five million cars during the peak years of 1947-1949. It is interesting to note that sometime during the latter part of 1947 we forecast that there will be as many cars in use as in 1941 with the possibility of a slightly higher unit consumption. In subsequent years we believe that the unit consumption will decline due to greater efficiency anticipated from new cars made beginning with 1948. The mileage that the cars will travel is forecast as being almost 10,000 miles per year which has been correlated with the disposable income figures on Table No. 1 and expressed to fluctuate in relation to these income changes. We have forecast that by 1950 the average new car will give actual performance at 25 miles to the gallon of gasoline. It is expected that this will be obtained under the average conditions of driving and not simply as a theoretic possibility. We have assumed that some of these improvements will take place as early as 1948 but with not quite so good a performance. Therefore we have calculated the new

Table No. 1

General Economic Factors 1939-1950

Year	*Labor Force* Total	Civilians Employed	*National Products in* Current Dollars	Wholesale 1926 Dollars	National Income (Net) Current Dollars	*Disposable Income in* Current Dollars	Cost of Living 1935-9 Dollars	*Price Indices* Wholesale 1926 Dollars = 100	Cost of Living 1935-9 Dollars = 100	Federal Reserve Board Index Production
	(Mill)	(Mill)	(Bill)	(Bill)	(Bill)	(Bill)	(Bill)			
1939	53.8	44.6	$ 88.6	$115.0	$ 70.8	$ 67.7	$ 68.2	77.1	99.4	108.0
1940	54.4	46.2	97.0	123.4	77.8	73.2	73.0	78.6	100.2	125.0
1941	56.4	49.7	120.2	137.0	96.9	88.7	84.3	87.3	105.2	162.0
1942	58.1	52.0	152.3	134.2	122.2	110.6	94.9	98.8	116.5	199.0
1943	63.2	53.1	187.4	181.6	149.4	124.6	101.0	103.2	123.1	239.0
1944	64.2	51.9	197.6	190.0	160.7	137.4	109.6	104.0	125.4	235.0
1945	62.8	50.4	197.3	186.7	161.0	139.7	108.7	105.8	128.4	203.0
1946	60.0	54.0	174.3	151.6	140.3	120.8	86.9	115.0	139.0	169.0
1947	59.8	54.8	179.4	152.0	144.0	124.1	86.2	118.0	144.0	190.0
1948	59.7	53.7	166.5	146.1	134.1	116.0	83.5	114.0	139.0	170.0
1949	59.6	53.6	157.5	150.0	126.8	109.6	82.4	105.0	133.0	160.0
1950	59.5	52.5	137.9	145.2	111.8	96.3	79.6	95.0	121.0	150.0

1948 cars to give only 20 miles to the gallon. These averages, of course, decline as the cars become older. For 1950 the calculations indicate an average performance for all cars then in use at 16.4 miles per gallon. This compares with present performance of about 14.9 miles to the gallon under average driving conditions and we doubt that during the war with its restricted stop and start driving it was possible to obtain more than 12 miles to the gallon.

Each of the classifications of uses by trucks, buses, tractors and miscellaneous were calculated separately, based upon numbers of vehicles in use, the business activity indexes and the continuation of the growth in use of buses and tractors. Some of the large increase in tractor consumption has been caused by a shift from the use of distillates to gasoline. In Table No. 2 we show these figures separately for several years.

Table No. 2

Analysis of Domestic Consumption of Gasoline by Trucks, Buses, Tractors and Miscellaneous Use (Thous. bbls. 42's Daily)

	1939-1941 Average	1946	1947	1950
Trucks	360	400	420	455
Buses	49	60	62	66
Tractors	72	125	130	143
Miscellaneous Uses	114	150	155	145
Total	595	735	767	809

An increasing amount of these requirements may be diesel fuel oil, particularly for buses and some of the larger trucks. No reliable data are available to determine the proportion of these fuels that are now or may be in the future be diesel and so for convenience we have shown all of this consumption under gasoline which might affect the yields shown in Table No. 14.

The forecasts of the consumption of aviation gasoline (Table No. 3) for commercial and civilian use indicate very rapid increases and by 1950 they would be more than double the 1946 consumption which in turn was three times as large as 1941. The military forecast indicates no consumption from refinery production in 1946 and the first half of 1947 as the high stocks held by the military may provide for their need. In 1947 and 1948 the total domestic military requirement upon refiners is shown as 20,000 B/D dropping to 15,000 B/D and in 1950 to 10,000 B/D. The lower requirements for aviation gasoline are offset by increases in jet propulsion fuel requirements. Jet propulsion fuel is included in the kerosene demand.

These details may be useful and are included not because we think they can be calculated nearly as accurately as some other portions of consumption but simply to form a basis for the appreciation of the fact that the requirements of aviation gasoline are going to be relatively small for some years to come. The production of aviation gasoline averaged about 500,000 barrels per day in the United States during 1944 and reached a peak of 600,000 B/D during that year.

If comparison is made between the 90,000 B/D average requirement after 1946 and the peak production during the war it can be seen that the production required declines to about 15- percent of that peak.

Total requirements for kerosene in 1946 are forecast at approximately 31 percent above 1941 levels. Total uses were forecast by correlation with income payments. The uses other than in tractors or for ranges were correlated with industrial production. Tractors and range oils were assigned the balance in proportion to indicated prewar relationships, allowing for some diversion to liquefied gases. It seemed impossible to obtain any clear picture of the probable requirements by space heaters or range burners which are the principal devices which utilize these fuels.

We have decided to include the No. 1 fuel oil sold for range burners because of the fact that these fuels are interchangeable and are generally marketed in a similar fashion whether the product is kerosene or No. 1 fuel oil. The estimates of the No. 1 fuel oil are included as a memorandum so that comparisons can be made with estimates of kerosene alone. These are also necessary to calculate the proper yields.

An extensive analysis was made of the relationship of sales of burners to new homes built and homes occupied in non-farm areas up to 5-family dwelling units. Each geographic area was considered separately. A premise was used as furnished by the Department of Commerce and others who have studied the problem as to the number of new homes that would be built in the postwar period. This assumption was calculated into the probable areas based upon population shifts and assumptions were made as to the relationship of burner sales to these new homes built as well as to the total occupied homes.

Consideration was given to the greater efficiency

Table No. 3

Aviation Gasoline Consumed at Domestic Airports or in Domestic Operations and Exports Bbls. 42's Daily)

	1946	1947	1948	1949	1950
Domestic Mainliners	20,000	28,000	30,800	33,900	67,300
Domestic Feeder Lines	600	1,320	2,180	2,300	2,500
Domestic Commercial (Cargo & Mail)	2,030	2,380	2,800	3,150	3,500
Private Flying	2,100	3,500	5,700	11,000	20,000
Engine Building	1,900	1,900	1,900	1,900	1,900
International Services—Departure	1,520	1,740	2,120	2,850	3,440
Total Excluding Military	28,150	38,840	45,500	55,100	68,640
Military		20,000	20,000	15,000	10,000
Grand Total—Domestic	28,150	58,840	65,500	70,100	78,640
Exports	22,000	27,000	22,000	20,000	18,000
Total Requirements	50,150	85,840	87,500	90,100	96,640

which would be built into the new burners to be sold after the war. This efficiency was applied to the new burners and a decreasing number of old burners were left with the pre-war efficiency applied to them. Consideration was also given to the carry-over of the permanent improvements made to homes during the war in order to decrease the consumption of fuel oil during wartime rationing, the change in heating habits, the lifting of restrictions on consumption, the reconversion back to oil of most of the burners converted to coal during the war and considerable weight was also given to the approaching saturation point for the conversion of non-oil users to oil users. Lower consumption per new home was assumed because of the trend toward smaller sized structures. Each of these items was developed by areas and gave the resulting consumptions per burner.

No effect was given to the possible conversion of one or both of the big pipe lines from Texas to New York to gas as their future use is still unsettled. It was estimated by Sidney A. Swensrud in a paper given before the American Institute of Mining and Metallurgical Engineers in February, 1944, that such conversion would have a tendency to decrease consumption of light fuel oil in this area to the extent of seven million barrels annually but that this level would not be reached for several years.

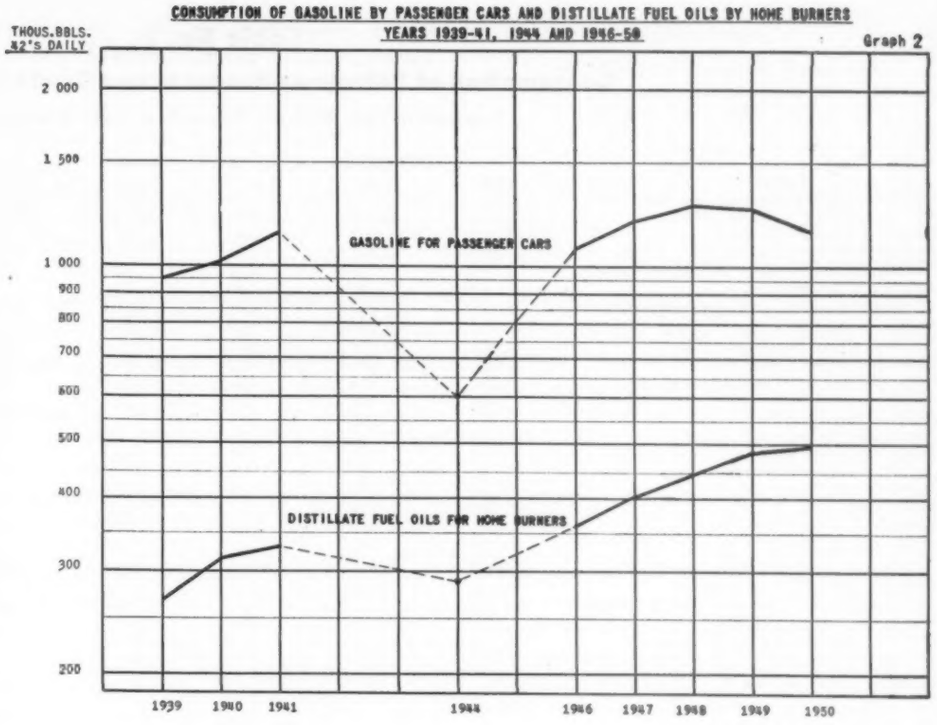
It is interesting to note that the numbers of oil burners in the postwar period are forecast to be substantially greater than in prewar. Unlike automobiles it is estimated that the number of burners in use in 1944 was about the same as 1941. We have forecast that there will be a considerable replacement market for new type burner-boiler installations which should considerably increase the efficiency of many of the present fuel oil appliances. An interesting comparison is also possible by noting that during 1950 it is forecast that the consumption of fuel oil by home burners will increase 85 percent over the 1939 use. When this is contrasted with the 24 percent increase in the consumption of gasoline by passenger cars the difference in these two trends is crystallized. Graph No. 2 illustrates these data.

As explained previously the greater efficiency expected from automobiles beginning in 1948 tends to retard the increase in the consumption of gasoline for passenger cars which might otherwise be expected. After this full effect has been felt then the consumption of gasoline should again increase in direct comparison with the number of vehicles and mileage travelled.

By 1950, with 3,750,000 oil burners in use, it is felt that about three-fourths of the total protential users will have been gained for oil. Calculations made in the various areas indicate that five million burners would be close to a saturation point similar to 40 million passenger cars which seems to be considered the saturation point

CONSUMPTION OF GASOLINE BY PASSENGER CARS AND DISTILLATE FUEL OILS BY HOME BURNERS
YEARS 1939-41, 1944 AND 1946-50

Graph 2



for those vehicles. Data on number of passenger cars and home burners are shown pictorially in Graph No. 3.

All Other Distillates

This heading includes the consumption of diesel oils as well as light fuels for industrial usage and in gas manufacture. As mentioned under the preceding section no consideration is given to the possible conversion of one or both large pipe lines to gas. If this takes place, it may reduce the requirements for gas enrichment. As indicated in Table No. 4 the major part of the increase in this category is looked for in diesel oils.

Table No. 4

Analysis of Domestic Consumption of All Other Distillates (Thous. Bbls. 42's Daily)

	Average 1939-1941	1946	1947	1950
Diesel	69	122	129	167
All Other Distillates	47	98	103	88
Total	116	220	232	255

AVERAGE NUMBER OF PASSENGER CARS IN USE AND AVERAGE NUMBER OF HOME OIL BURNERS IN USE
YEARS 1939-41, 1944 AND 1946-50

Graph 3

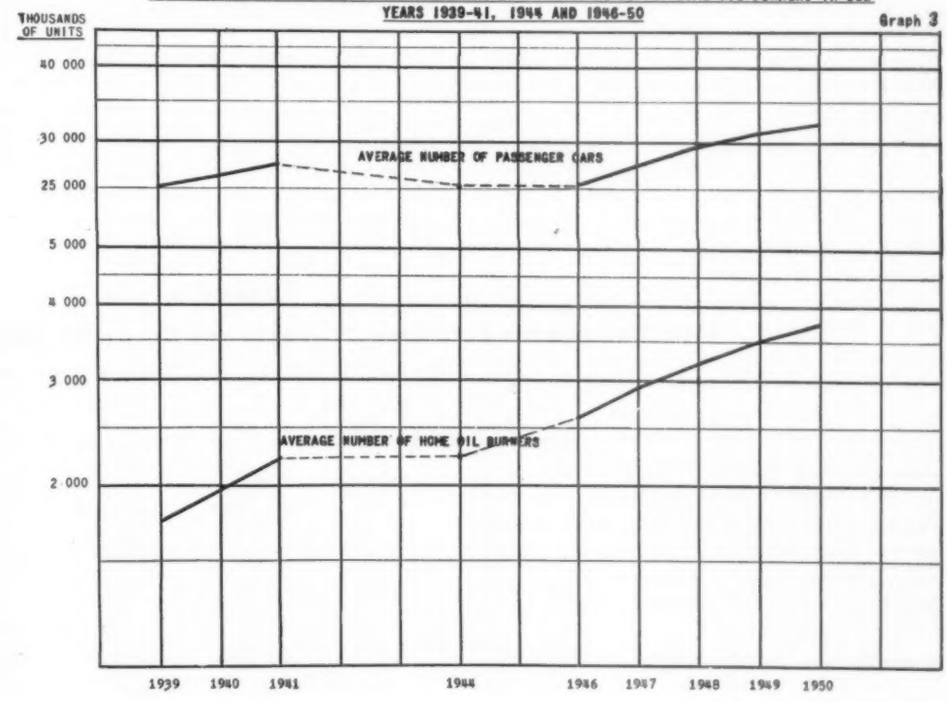


Table No. 7

Consumption of Petroleum Products and Crude Oil in the U. S.

Expressed in Daily Averages, Thousands of Units or Barrels of 42s

ITEM	HISTORY 1939	1940	1941	WAR 1944	1946	FORECAST 1947	1948	1949	1950
Av. No. of Pass. Cars in Use	25,036	26,073	27,382	25,378	25,405	27,260	29,510	31,010	31,960
Cons. per Car per Year	13.88 bbl.	14.29 bbl.	15.26 bbl.	8.65 bbl.	15.50 bbl.	16.00 bbl.	15.60 bbl.	14.60 bbl.	13.54 bbl.
Consumption by Pass. Cars	953	1,017	1,146	600	1,080	1,196	1,265	1,238	1,186
Trucks, Buses, Tractors and Misc. Cons.	551	579	653	725	745	767	794	813	809
Aviation Consumption	10	15	30	209	28	59	66	70	79
Total Cons. Naphtha and Gasoline	1,514	1,611	1,829	(1) 1,534	1,853	2,022	2,125	2,121	2,074
*Kerosene and #1 Fuel Oil (a)	173	196	201	200	256	260	258	260	260
Av. No. Home Burners in Use	1,749	1,974	2,243	2,254	2,597	2,925	2,240	3,518	3,738
Cons. per Burner per Year	†57.77 bbl.	†56.43 bbl.	†56.76 bbl.	†46.70 bbl.	50.70 bbl.	50.30 bbl.	50.10 bbl.	49.10 bbl.	48.10 bbl.
Cons. of Dist. by Home Burners (a)	266	316	331	289	361	404	445	473	493
All Other Distillates (a)	105	112	131	(2) 225	220	232	240	245	255
All Residual Fuel Oils	873	924	1,044	(3) 1,254	1,224	1,249	1,195	1,182	1,156
Automotive Lubes. (Incl. Avia.)	34	35	39	37	39	46	47	48	49
Industrial Lubricants and Marine (b) (Incl. Wax and Non Pet. Prod.)	38	38	52	60	51	57	54	50	47
Asphalts and Road Oils	94	97	122	(4) 107	131	156	151	152	146
Misc. (Incl. Coke & L.P.G.)	38	34	55	107	99	101	103	105	107
Refinery Loss and Still Gas	203	217	224	315	303	310	310	304	296
Crude Oil as Such	36	46	38	34	38	38	38	38	38
Grand Total All Products	3,374	3,626	4,066	4,162	4,575	4,875	4,966	4,978	4,921
* Memo—#1 Fuel Oil Included	8	11	12	14	16	17	18	18	17
(a) Memo—Total Kero. & Dist. Fuel Oils	544	624	663	714	837	896	943	978	1,008
(b) Memo—Wax Included	3	3	5	6	5	6	6	6	5
" " Additives & Misc. Included	3	3	3	4	4	4	4	4	4

(1) Includes +9 TBD imported gasoline and —144 TBD for exports and other adjustments.
(2) Adjusted —15 TBD for exports and +12 TBD for imports.
(3) Adjusted —86 TBD for exports and +98 TBD for imports.
(4) Adjusted +2 TBD for imports.
(†) Averages corrected to normal weather.

Table No. 8

Exports from the United States of Petroleum Products and Crude Oil

Expressed in Daily Averages, Thousands Barrels 42s

ITEM	HISTORY 1939	1940	1941	WAR 1944	1946	FORECAST 1947	1948	1949	1950
Aviation Gasoline	N.A.	13	62	300	22	27	22	20	18
Other Naphtha & Gasoline	122	56	12	180	180	141	142	140	137
Total Naphtha & Gasoline	122	69	74	480	202	168	164	160	155
Kerosene	22	9	9	24	21	24	19	14	10
Distillate Fuel Oils	88	52	46	163	76	33	35	38	40
Residual Fuel Oils	48	44	45	179	102	62	48	34	21
Lubricants & Wax	33	29	27	24	26	28	27	25	24
Asphalts & Road Oils	3	4	4	2	6	8	6	4	2
Miscellaneous	4	8	9	7	4	4	4	4	4
Total Products	320	215	214	879	437	327	303	279	256
Crude Oil	197	141	91	95	89	88	85	85	85
Total Crude & Products	517	356	305	974	526	415	388	364	341

Table No. 9

Total Demand for Petroleum Products and Crude Oil (Domestic Plus Exports)

Expressed in Daily Averages, Thousands Barrels 42s

ITEM	HISTORY 1939	1940	1941	WAR 1944	1946	FORECAST 1947	1948	1949	1950
Aviation Gasoline	10	28	92	509	50	86	88	90	97
Other Naphtha & Gasoline	1,626	1,652	1,811	1,505	2,005	2,104	2,201	2,191	2,132
Total Naphtha & Gasoline	1,636	1,680	1,903	2,014	2,055	2,190	2,289	2,281	2,229
Kerosene (Including #1 Fuel Oil)	195	205	210	224	277	284	277	274	270
Distillate Fuel Oils (Including Diesels)	459	480	508	677	657	669	720	756	788
Residual Fuel Oils	921	968	1,089	1,433	1,326	1,311	1,243	1,216	1,177
Lubricants & Wax	105	102	118	121	116	131	128	123	120
Asphalts & Road Oils	97	101	126	109	137	164	157	156	148
Miscellaneous (Incl. Coke & L.P.G.	42	42	64	114	103	105	107	109	111
Refinery Loss & Still Gas	203	217	224	315	303	310	310	304	296
Total Products	3,658	3,795	4,242	5,007	4,974	5,164	5,231	5,219	5,139
Crude Oil—Export & Used as Such	233	187	129	129	127	126	123	123	123
Total Crude & Products	3,891	3,982	4,371	5,136	5,101	5,290	5,354	5,342	5,262

Residual Fuel Oils

We show in Table No. 5 each of the large classifications of domestic users of residual fuel oils that have been studied and forecast separately. Fuel oil for industrial heating was forecast to increase fairly rapidly until 1949 and then level off at about 200,000 barrels per day. It was assumed that 90 percent of the burners previously in use would be reconverted to oil as soon as product was available and that new installations would be fairly substantial. As indicated in Table No. 5 we have forecast that the bunkering of vessels would be substantially higher in the postwar period than in the prewar and that the Navy would use about twice as much as it did in 1940 and even more than that in the years immediately ahead. We have assumed that a considerable portion of this requirement for vessels and by the Navy will be met by imports and in the calculation of yields and requirements for crude oil we have assumed that in the year 1946 imports of residual fuel oil will be 103,000 barrels per day and might increase in 1948 to 150,000 barrels per day and thereafter be as high as 200,000 barrels par day. If these imports are not made, of course, the domestic requirements may be increased to the extent of any deficiency.

There are several reasons for assuming the continuation of relatively large residual fuel imports and an increase in these imports in the future. Domestic refiners have installed equipment by which they are able to convert a much larger portion of crude oil than heretofore into more valuable products such as gasoline, kerosene and distillate fuel oils. On the other hand a considerable portion of the crude oil production in the Caribbean area lends itself to a very high production of residual fuel oil so that in effect this nearby source is complementary to domestic production. It seems perfectly logical, therefore, that imported residual fuel oil should be counted upon to meet some of the large demand for industrial fuel oils, particularly for ships' bunkers and Navy use. Other industrial uses are not too difficult to forecast because their correlation with the FRB industrial production index is fairly good. Within reasonable postwar limits, every change of one percent of the FRB index numbers will cause a change of ½ percent in consumption of residual fuels by industry. When the index numbers are around 190, this one percent change would be equivalent to a change of 1.9 index numbers. When the FRB index declines to 150, it would mean 1.5 index numbers. However, in trying to forecast the takings by the Navy or commercial vessels from the U. S. we have a very much different problem. International prices, import duties and other factors affect these. Nevertheless, we believe that the bunker business supplied by domestic refiners will be considerably larger than before the war for the next couple of years.

Table No. 5

Analysis of Domestic Uses of Residual Fuel Oils

(Thous. Bbls. 42's Daily)

	Average 1939-1941	1946	1947	1950
Heating	120	152	167	195
Vessels	167	210	194	188
Navy-Army	48	125	100	85
Gas & Electric Plants	82	91	101	84
All Other	530	646	687	604
Total	947	1224	1249	1156

Automotive Lubricants (Including Aviation)

Forecasts were made of the uses of these products for each of the categories shown for gasoline consumption. The ratio to gasoline method was employed which over the past has given the best forecast of these usages. Trends of the ratio to gasoline were varied according to the best opinions obtainable. The final ratios in 1950 were assumed to be just under the pre-war ratios

Industrial Lubricants & Marine (Including Waxes and Non-Lubricants)

It has been found that the consumption of these products has a fairly good correlation with the Federal Reserve indexes of production. Several other correlations were made and while they all tended to show the same trend in the postwar period they gave answers which varied considerably as to the level of consumption. These were not used in our final work. It was felt that the more recent trends which gave a much better correlation with the FRB indexes were more reliable. These also gave the lowest trend of consumption. These results were averaged with the old long-time trends and the resulting estimates used.

Asphalt and Road Oils

These forecasts were based upon a detailed and separate analysis of these products for road construction, roofing and industrial uses. In our opinion there has been built up during the war a considerable deficiency in road construction which may now amount to as much as 29,000 miles. We believe that this deficiency will be made up after the war in addition to a very extensive normal road building program. It was found that road construction showed a good correlation with "National Product" expressed in wholesale dollars of current purchasing power each year. The roofing section of this consumption was based on a high business activity after the war which is clearly indicated from the great home building deficiency which has pyramided during the war. The industrial uses of asphalts while small are calculated from a correlation with FRB production indexes. An analysis of these consumptions is given in Table No. 6.

Miscellaneous (Including Coke)

These are relatively small items including liquefied petroleum gases. The larger forecast used in the post-war period contemplates a considerable expansion in this liquefied petroleum gas market. It is also believed that production of chemicals from petroleum will increase and the forecast consumption includes this expansion. Other products such as butadiene and toluene have been cut materially from the quantities consumed during the war period. The high consumption during 1944 as estimated may include adjustments of other products which may not have been reported entirely accurately during this period.

Table No. 6

Analysis of Asphalt & Road Oil Domestic Consumption

(Thous. Bbls. 42's Daily)

	Average 1939-1941	1946	1947	1950
Road Construction	76	98	120	115
Roofing	22	25	27	24
Industrial Use	7	8	9	7
Total	105	131	156	146

Refinery Loss & Still Gas

The expansion that has taken place in the gas proportion of refinery output has been very great during the war but it is forecast that this high level will not continue into the postwar period because of the lesser aviation gasoline requirements.

Crude as Such

This figure was necessary in order to provide for the use of crude on producing leases and the losses in transporting crude from the wells to the refineries. It amounts to a little less than one percent of total amount handled and is a fairly constant figure.

Exports from the United States

Recent studies seem to indicate that the United States will be called upon to furnish a much larger volume of some products than had been previous forecast. These studies are based upon a country by country requirements forecast and estimates of the future production from refineries now in operation or which may be built in foreign countries within the period. During 1940 and 1941 exports were materially reduced because of the war in Europe. Prior to those years exports were inflated due to war preparations. The exports that we forecast of products are considerably higher during the next five years than they were for the five years prior to the war, and even by 1950 product exports may be about the same as the prewar averages. We have forecast crude exports at only half of the prewar averages as, in our opinion, the previous exports to Japan, France, Italy and other countries will be negligible in the future.

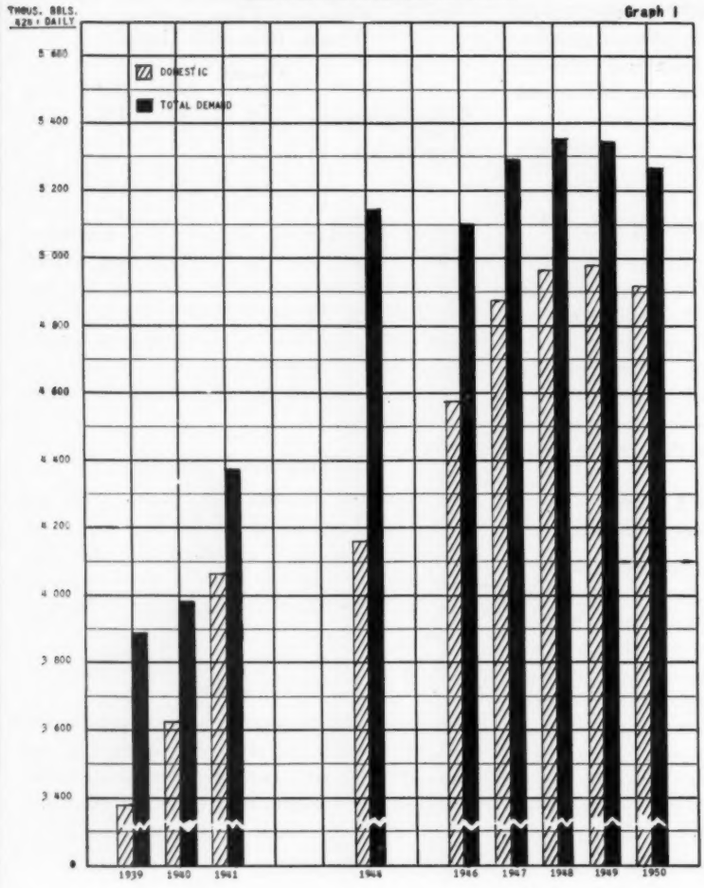
Crude Requirements for Runs to Stills

In order to calculate a crude oil requirement for runs to stills from the product demand forecasts it was necessary to eliminate several sources of petroleum products which do not involve crude oil production within the United States. These are:

(1) Production of natural gasoline, condensate and benzol.

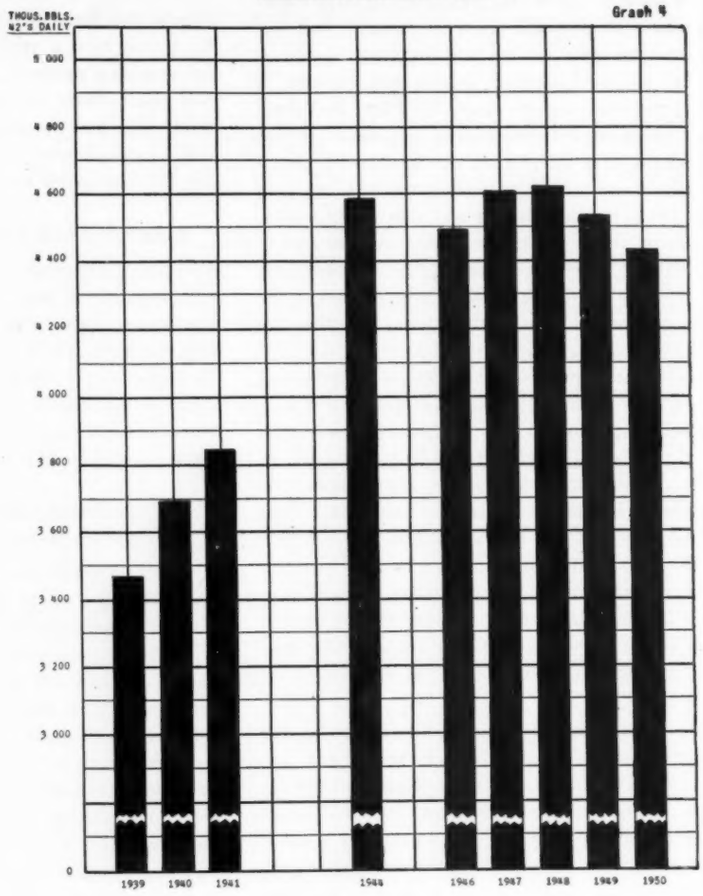
DEMAND FOR PETROLEUM PRODUCTS AND CRUDE OIL - U.S.
YEARS 1939-1941, 1944 AND 1946-1950

Graph 1



REQUIREMENTS FOR CRUDE OIL PRODUCTION IN U.S.
YEARS 1939-41, 1944 AND 1946-50

Graph 4



(2) Imports of finished products into the United States.
(3) Production from Methane Gas.
(4) Use of Non-Petroleum additives.

In addition to the above the total demands shown in Table 7 include crude oil exported, transferred to fuel oil and other uses and losses of crude oil. As these do not become demand upon refineries, they must also be eliminated in order to arrive at the crude oil which may be charged to stills to satisfy the finished product requirements. Changes in finished product inventories enter into this calculation and are shown separately. Due to the fact that the inventories at the beginning of 1946 were somewhat lower than normal, particularly for fuel oils and kerosene, the table indicates that in order to reestablish sufficient inventories at the end of the year refiners might be called upon to process 55,000 barrels per day of crude oil for this purpose. As the total demands are not estimated to change materially from 1946 levels no further inventory changes for products have been shown although there may be small additions.

The conclusions are that the required crude runs to stills might increase during the next two years and reach their highest level during the year 1948. After that the reduction in exports or domestic requirements and the greater amounts anticipated from natural gasoline and imports of residual fuel oil seem to indicate lower crude oil runs. The decline indicated for 1950 is on the assumption that industrial activity during that year might decline with a resultant smaller demand for some petroleum products. In addition to this the use of passenger car gasoline is assumed to drop off, reflecting the greater economy mentioned previously. All of these calculations are shown in Table No. 12.

Crude Oil Production Required in the United States

From Table 12 we have the requirements of crude for runs to stills. The producer is interested in the determination of requirements of total production of crude. In addition to the crude runs to stills the producer must take into consideration crude required for exports, transfers to fuel and other uses and losses. On the other hand, some crude has historically been imported into the United States and there is every indication that this will continue at about current levels of approximately 225,000 barrels daily and after 1946 it is forecast that this will increase to approximately 250,000 barrels daily.

The necessity of importing some crude into the United States has been the subject of inquiry from various quarters. Much of this crude oil

(Continued on page 130)

Aviation Gasoline Demand (b)
Other Gasoline Demand
Deduct Natural Gaso. Condensate & Benzol, etc.
Net other Gasoline Demand
Total Gasoline From Crude
Kerosene Demand
Deduct #1 Fuel Oil (Produced as Fuel Oil)
Kerosene From Crude
Distillate Fuel Oil Demand
Add: From Kerosene #1 Fuel Oil
Deduct: Transfers From Crude
Imports
Net Distillate Fuel Oil From Crude
Memo: Kero. & Dist. Combined From Crude
Residual Fuel Oil Demand
Deduct: Imports
Transfers From Crude
Net Residual Fuel Oil From Crude
Lubricants Demand (Including Wax)
Less: Additives
Net Lubricants & Wax From Crude
Asphalt and Road Oils Demand
From Crude
Misc. Demand (Incl. Liquefied Pet. Gas)
Deduct: From Natural Gaso. & Condensate
Net Misc. From Crude
Still Gas and Loss
Inventory Build Up
Crude Runs to Stills

Table No. 12

Crude Requirements for Runs to Stills

Thousands Bbls. 42s Daily

ITEM	HISTORY 1939	1940	1941	WAR 1944	1946	FORECAST 1947	1948	1949	1950
Total Demand—Table No. 9	3,891	3,982	4,371	5,136	5,101	5,290	5,354	5,342	5,262
Deductions									
Prod. of Natural Gaso. Condensates & Benzol	148	161	232	280	335	355	375	395	415
Prod. of Gasoline from Methane							10	15	20
Imports of Products	71	112	127	131	118	140	165	215	215
Crude Exports	198	141	91	94	89	88	85	85	85
Crude Transfers to Fuel	34	28	42	87	60	60	60	60	60
Crude Used as Such & Balances	36	45	38	36	38	38	38	38	38
Non Pet. Products in Lubricants		1	2	2	2	2	2	2	2
Total Deductions Sub-Total	487	488	532	630	642	683	735	810	835
Add—Increase in Finished Products Inventories	—13	42	22	45	55				
Crude Runs Required	3,391	3,536	3,861	4,551	4,514	4,607	4,619	4,532	4,427

Table No. 13

Crude Oil Production Required in United States

Thousands Bbls. 42s Daily

ITEM	HISTORY 1939	1940	1941	WAR 1944	1946	FORECAST 1947	1948	1949	1950
Crude Runs to Stills	3,391	3,536	3,861	4,551	4,514	4,607	4,619	4,532	4,427
Add—									
Crude Oil Exports	198	141	91	94	89	88	85	85	85
Crude Transfers to Fuel	34	28	42	87	60	60	60	60	60
Crude Used as Such & Balances	36	45	38	36	38	38	38	38	38
Increase in Crude Stocks	—102	64	—52	—61	19				
Sub-Total	3,557	3,814	3,980	4,707	4,720	4,793	4,802	4,715	4,610
Less Crude Oil Imports	91	117	139	123	225	250	250	250	250
Crude Oil Production Required	3,466	3,697	3,841	4,584	4,495	4,543	4,552	4,465	4,360

Table No. 14

Percentage Yield From Crude Runs to Stills

Thousands Bbls. 42s Daily

HISTORY						WAR				FORECAST									
1939 (a)		1940 (a)		1941 (a)		1944 (a)		1946		1947		1948		1949		1950	
Barrels	% Yield	Barrels	% Yield	Barrels	% Yield	Barrels	% Yield	Barrels	% Yield	Barrels	% Yield	Barrels	% Yield	Barrels	% Yield	Barels	% Yield
10	0.3	28	0.8	92	2.4	509	11.2	50	1.1	86	1.9	88	1.9	90	2.0	97	2.2
1,626		1,652		1,811		1,505		2,005		2,104		2,201		2,191		2,132	
150		159		210		234		267		282		307		327		347	
1,476		1,493		1,601		1,271		1,738	38.5	1,822	39.5	1,894	41.0	1,864	41.1	1,785	40.3
1,525	45.0	1,526	43.2	1,711	44.3	1,797	39.5	1,788	39.6	1,908	41.4	1,982	42.9	1,954	43.1	1,882	42.5
195		205		210		224		277		284		277		274		270	
8		11		12		14		16		17		18		18		17	
188		5.5	5.7	199	5.2	214	4.7	261	5.8	267	5.8	259	5.6	256	5.6	253	5.7
459		480		508		677		657		669		720		756		788	
8		11		12		14		16		17		18		18		17	
8		7		7		9		8		8		8		8		8	
		9		14		19		15		15		15		15		15	
443	13.1	502	14.2	518	13.4	653	14.4	650	14.4	663	14.4	715	15.5	751	16.6	782	17.7
631	18.6	703	19.9	717	18.6	867	19.1	911	20.2	930	20.2	974	21.1	1,007	22.2	1,035	23.4
921		968		1,089		1,433		1,326		1,311		1,243		1,216		1,177	
43		80		102		99		103		125		150		200		200	
26		21		36		78		52		52		52		52		52	
838	24.7	864	24.4	938	24.3	1,261	27.7	1,171	26.0	1,134	24.6	1,041	22.6	964	21.3	952	20.9
105		102		118		121		116		131		128		123		120	
		1		2		2		2		2		2		2		2	
101	3.0	105	3.0	115	3.0	120	2.6	114	2.5	129	2.8	126	2.7	121	2.7	118	2.7
97		101		126		109		137		164		157		156		148	
96	2.8	102	2.9	124	3.2	109	2.4	137	3.0	164	3.6	157	3.4	156	3.4	148	3.3
42		42		64		114		103		105		107		109		111	
N.A.		N.A.		17		35		68		73		78		83		88	
29	0.9	30	0.8	40	1.0	75	1.6	35	0.8	32	0.7	29	0.6	26	0.6	23	0.5
203	6.0	217	6.1	224	5.8	315	6.9	303	6.7	310	6.7	310	6.7	304	6.7	296	6.7
—13		42		22		45		55	1.2								
3,391	101.0	3,536	100.3	3,861	100.2	4,551	99.8	4,514	100.0	4,607	100.0	4,619	100.0	4,532	100.0	4,427	100.0

(a) For these years the deductions or additions to the indicated demand for products do not balance as do the forecast years. This is due to the inventory changes not being shown on this report to balance same. Product yields vary from 100% due to changes in unfinished stocks.

(b) The percentage yields for Aviation Gasoline covering the years 1939-44 are somewhat different from those reported by the Bureau of Mines. The above Aviation Yields were based upon Demands and not Production.

RECENT DEVELOPMENTS IN THE

By A. A. Neff and G. H. S. Snyder

FOR more than ten years increasing attention has been given to additives as a means of imparting certain specific characteristics to lubricating oils. Prior to this period, improvements in the performance of lubricating oils were obtained by the subtractive refining (i.e. the removal of undesirable components) of stocks from carefully selected crudes by acid, solvent or clay treatment or combinations of these. Even today straight petroleum oils are giving satisfactory service in many different types of applications but design trends and service requirements are emphasizing the desirability, if not the necessity, of using additive type oils.

The requirements of the armed services during the war for tremendous supplies of lubricating oils of the "heavy duty" type to lubricate various types of spark ignition as well as diesel engines (in order that there would be simplification of supply was well as application) necessitated the use of all-purpose additive oils. Also, the demand for special lubricants having characteristics not obtainable from petroleum alone gave tremendous impetus to the use of additives. The outstanding success obtained by the use of many of these additive oils under combat conditions has led to their widespread acceptance in our peacetime economy.

It would be well to interject a word of caution at this point to the effect that the use of additive oils per se is not a cure-all, as the overall performance characteristics of additive oils is a function of the response of the particular base stock to the addition agent involved and the latter's potency.

The limitations of subtractive refining alone have long been recognized, particularly before the advent of solvent refining. When only sulfuric acid and clay treatment were available the viscosity indices obtainable on finished oils, for example, were definitely restricted and dependent upon the crude source. Resin removal from residual stocks under these treating conditions, was rather incomplete and to attempt total removal resulted in an over-refined oil of reduced oxidation stability. However, where distillate stocks alone were involved, and proper selection of acid treatment and crude source was made, outstanding products resulted. This type of lubricant is giving entire satisfaction today in many applications despite the widespread use of additives.

With the advent of solvent treatment, considerably greater flexibility was realized both with respect to actual refining technique and quality levels attainable as compared with acid treatment of residual stocks, but it was recognized that solvent refining did not have overall applicability with respect to the manufacture of premium oils from distillates.

When refining residua after solvent treating was made available a number of operations were possible as follows:

(1) Single solvent extraction of low asphalt, content residua, as for example Pennsylvania stocks.
(2) Asphalt removal by distillation followed by single solvent extraction.
(3) Asphalt removal with acid followed by solvent extraction.
(4) Solvent (propane) deasphalting followed by single solvent extraction.
(5) Solvent (propane) deasphalting and solvent extraction as a unit operation ((3) above being considered as two distinct operation).

The particular choice of any of the preceding operations depended largely on the type of charge stock available. The quality of the product obtained was dependent on the choice of the charge stock and specific treating conditions involved. The advantages of using the processes outlined over simple acid treatment from the quality point of view, were that there was more complete removal of resin-like materials and aromatics which resulted in an overall rise in quality with respect to viscosity index and oxidation stability.

The solvent refining of distillate stocks resulted, as in the case of residua, in products having higher viscosity indices than attainable with acid treatment, but for those products which were required to withstand long periods of operation, solvent refined neutral oils did not in general give the required stability. However, there have been examples wherein by the use of distillate

A. A. Neff, Superintendent, Paulsboro, N. J. Refinery, of the Socony-Vacuum Oil Company, Inc., has devoted 21 years mainly to lubricating oil processing for Socony-Vacuum. A graduate of Carnegie Institute of Technology, Mr. Neff spent one year with the Department of Public Highways before joining Socony-Vacuum in 1925.

Lubricating oil compounding room, pump room header, Paulsboro, N. J. refinery, Socony-Vacuum Oil Company, Inc.

MANUFACTURE OF LUBRICATING OILS

G.H.S. Snyder, supervisor of Lubricating Oil Division, Research and Development Laboratories, Paulsboro, N. J. was graduated from George Washington University in 1929 and following two years with the Bureau of Standards was employed by Socony-Vacuum. For the past 15 years, Mr. Snyder has been engaged in lubricating oil research and development work.

stocks from carefully selected crude sources refined under adequately chosen solvent extraction conditions, products of excellent quality have been manufactured.

Despite the general high quality levels attained by means of the subtractive refining processes, it was obvious in many instances that this was not sufficient. Advances in machine design with the objective of higher power output with reduced weight and size placed increasing burdens on the lubricating oil. The desire for lower maintenance costs by lengthening overhaul or lubricating oil drain periods emphasized these. Thus it became necessary, for certain lubricating oil applications, to supplement the subtractive refining processes by the use of additives to impart properties inherently unobtainable from petroleum alone.

The use of additives appeared sporadic at first, because of the limited need for them, but as design and operation were advanced in efficiency and the science of additive application was developed, this use became more general. The success of straight petroleum oils in many applications and the specificity of some of the earlier additives were probable reasons for the apparent slow trend toward widespread usage, but just prior to the war additive oils were finding fair acceptance.

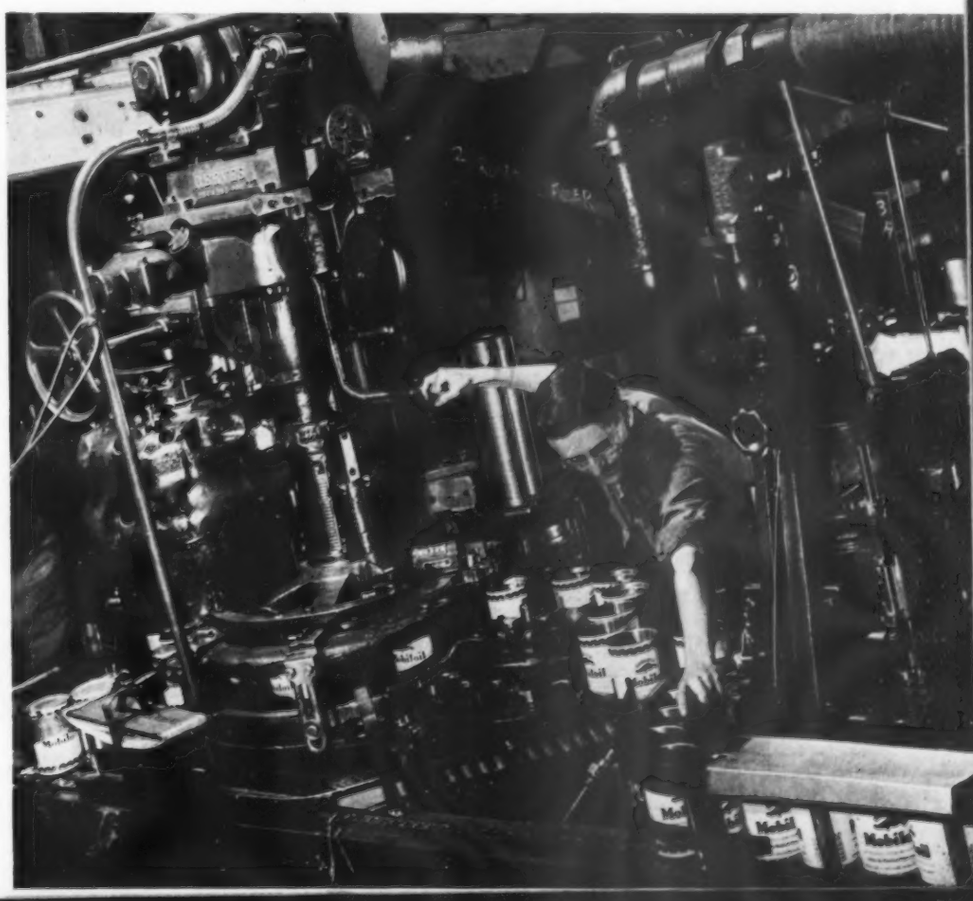
With the advent of the war it was obvious that additive type oils would play an extremely important role. The armed services required extremely large volumes of lubricants for a multiplicity of purposes. Because of complications of supply and in order to avoid misapplication, it was desirable to simplify the specifications for lubricating oils and thus decrease the number required. The so-called "Heavy Duty Oil" was one result of this. Prior to the war at least three classes of oils were required to satisfactorily lubricate the types of engines used by the Army for combat vehicles. A co-operative program between the builders, the refiners and the Army, through the medium of the Co-operative Research Council resulted in a specification which required lubricants capable of satisfactorily lubricating all the vehicles involved. As the standardization of the services on such practices required the use of additive oils, research on additives and their application was rapidly expanded by both refiners and additive suppliers to provide the necessary supplies.

Difficulties encountered by the Navy with respect to the rusting of turbine systems and general oil deterioration under certain combat conditions emphasized the critical need for an improved marine turbine oil, with the result that a specification was established to eliminate these shortcomings. Here again additives were the solution and combat service proved the lubricants developed for this purpose.

Aircraft hydraulic fluid is an outstanding example of one of the specialized types of lubricants required by the armed services. Here viscosity indices of about 200, chemical characteristics with respect to compatibility with various types of synthetic rubber gaskets, oxidation stability, non-corrosivity with respect to various alloys and more recently rust prevention, required unique processing with regard to both lubricating oil refining and crude selection as well as additive selection. As a matter of fact, early work on this problem showed definite specificity with respect to the additive used as a viscosity index improver. For example, some materials which imparted the required viscosity index (i.e. viscosity relationship at 100°F. and 210°F.) and the specified —40°F. viscosity when determined in the usual manner, proved to thicken excessively when kept at —40°F. for periods of one hour or more. As bombing missions were of many hours duration, this was an important factor and viscosity index improvers were developed to meet this single requirement.

Later in the war, difficulties with the VVL-761 specification (extreme pressure) type lubricant in low speed-high torque (off the road) type of operation showed the need for an extreme pressure type of lubricant having wider application, and the specification was revised to assure the proper balance of operating characteristics over the range of low speed-maximum output to high speed operation.

Canning plant of the Paulsboro, N. J., refinery of the Socony-Vacuum Oil Company, Inc.



The humid conditions encountered in the South Pacific caused much trouble because of the rusting of equipment not only in transit but also during service and rust inhibitors were a necessity for satisfactory service under these conditions. Developments on this phase of work are being continued because solutions were not found for all conditions by the end of the war and research in this field will have a variety of commercial applications.

The four types of developments cited above in connection with war-time research on lubricating oils are just a few examples of changes required by combat conditions which expedited utilization of additives. The remainder of this discussion will pertain primarily to lubricating oil developments as they are reflected in the products of today.

Superior lubricants for conventional (piston) type aircraft engines are manufactured today by the subtractive refining of stocks from carefully selected crudes. While additives (with the exceptance of pour point depressants) have not yet found wide acceptance in this field on a commercial basis, development work has shown that detergent type additive oils can effect considerable improvement with respect to engine cleanliness and thus tend to lengthen overhaul periods. However, other factors such as wear and deposits from the lead in the fuel have caused some delay in this development.

The rapid development of the continuous combustion engine for aircraft, both the jet and turbo-propeller type, has presented a number of problems concerning lubricating oil. The major problem has been to maintain the required lubricating quality despite the low viscosity required for high altitude flight and engine starting. As most jet engines operate on the principle of an all loss lubricating system with the lubricant flashing off the inner races of the bearings towards the turbine, it is axiomatic that the lubricant be entirely volatile at the temperatures encountered. Straight petroleum oils have been developed by careful selection of stocks and refining procedure which meet these conditions.

Experimental turbo-propeller engines have been lubricated satisfactorily with petroleum oils but tests have shown that to obtain maximum efficiencies, additive type oils definitely will be required. Because of the expense involved both for operation and equipment, full scale testing has been delayed but small scale tests definitely show advantages to be gained by the use of "lubricity" type additives for this purpose where high power outputs will be required through the use of reduction gears kept as small as possible for weight economy.

Truck, bus and passenger vehicle engine lubricants of today are reflecting the advances in technology gained during the war years. Prior to the war, chemical type addition agents were only in moderate use in lubricants for vehicular service, but experience gained during the war showed that the use of oxidation inhibitors (bearing corrosion preventives) and detergents in carefully selected base stocks would afford quality levels not attainable any other way with respect to bearing corrosion and general engine cleanliness. Since the war, the application of addition agents has gained widespread popularity in motor oils because of their outstanding performance both in heavy duty truck and bus operation and in passenger car service where "dirty" engines were encountered. The major contribution of additives to heavy duty operation has been the reduction in failures due to bearing corrosion, ring sticking and in general engine cleanliness which has, of course, materially reduced maintenance costs by lengthening overhaul periods and improving efficiency with respect to fuel consumption. In passenger car service, the use of improved additive type oils has similarly improved efficiency through their tendency to clean up dirty engines and by this same means reduced the number of necessary engine overhauls. Further, as newer model higher output engines become available, operating under higher speeds and temperatures, the need for modern additive type engine oils will become more apparent.

As has been pointed out, progress in development and application of additive type oils has been greatly accelerated by the war and the benefits of this experience are being rapidly applied to civilian operation. However, it might be well at this point to pause and remember the manifold functions a satisfactory lubricant must perform in order to protect and keep the equipment running at top efficiency. To do the job of reducing friction and wear, protecting against corrosion, dissipating large quantities of heat, and keeping the engine parts clean and free so that there is no interference with their action or the flow of heat, requires very careful balancing of materials, processing and handling.

While additives have been receiving most of the publicity regarding the satisfactory manner in which the newer lubricants have performed under increasingly severe service, additives alone are far from the whole answer. Crude selection, type and degree of refining are the essential foundation on which performance of the final product is built. Crudes vary in their response to treatment and care must be taken to avoid over refinement to enhance one characteristic such as VI to the detriment of stability or inhibitor response of the base stocks.

Additive selection also involves careful consideration of numerous factors to assure adequate potency and compatibility with base stocks involving repeated trial in laboratory bench, prototype and full scale equipment to achieve the ideal marriage in which base stock and additive complement in each other to produce the desired level of all around performance. Last but most important is extensive service testing in field equipment which remains the only reliable and proven yardstick of quality, and guarantee of performance characteristics.

In the field of industrial circulating oils, the use of the additive type product is finding increased usage as a result of its successful application during the war. This is particularly true of turbine oils. Prior to the war, additive type turbine oils did not have wide acceptance due to the successful use of certain outstanding straight petroleum oils. However, war-time problems, particularly rust formation in naval vessel propulsion gear accelerated the use of additives as a means of controlling this difficulty, which some years ago probably would not have been considered primarily as a function of the lubricant. Also, while the rust formation generally was not to the extent of appreciably affecting the materials of construction from an engineering standpoint, the complexity and close clearances of governor control systems made it imperative that there be no interference due either to rust formation in the mechanisms or to accumulation of corrosion products carried in the oil stream. In addition to the danger of control mechanism sticking, assurance against oil line stoppage to bearings and reduction gears and the possible abrasive action of corrosion products on these surfaces or their action as oxidation catalysts in promoting lubricant deterioration was essential.

It is interesting to note that in the case of turbine oils it was necessary to use a combination of oxidation and rust inhibitors because of the particular effects of either of these additives when used alone. Straight mineral oils normally generate rust preventive type materials on oxidation so that the use of oxidation inhibitors alone which prevent the formation of these surface active type materials make it desirable to add rust preventives to the new oil containing oxidation inhibitors. Also, effective rust inhibitors tend to catalyze oxidation so that it is desirable to use an oxidation inhibitor along with the rust preventive to check this tendency. In this particular instance it should also be noted that the use of rust preventive type turbine oils has been observed to allow rusting in installations where there is accumulation of excessive water. This serves to illustrate that the use of additives does not guarantee satisfactory service under all operating conditions.

It would be impossible to cite all the instances where combinations of effective additives with carefully chosen mineral oil base stocks have effected marked improvement in overall performance, or have prepared the way for increased power outputs and production records which a few years ago were only in the realms of hopes. The several examples that have been reviewed do point to the trend and are illustrative of what can be done by utilizing to the optimum degree recent developments in substrative or "clean up" refining techniques and then where existing or desired future developments require, stepping up overall performances levels by judicious choice of additives to impart specific characteristics.

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WORLD REFINERY CONSTRUCTION ENTERS NEW STAGE OF EXPANSION

(Continued from page 81)

The construction plans include not only full facilities for commercial manufacture of lubricating oils but also call for a number of pilot plants in which improvements in lubricating oil manufacture developed by laboratory research may be tested under actual operating conditions before being applied to quantity production. Contracts for this construction have been awarded to the Lummus Company and the M. W. Kellogg Company.

In May of this year, Shell's new cycling plant at Sheridan in Colorado County, Texas, was dedicated. Ground was broken for this plant, Shell's first, on January 7, 1944 and partial production began in August, 1945. The designed throughput capacity is 100,000,000 cubic feet of gas per day. From this wet gas there can be extracted 6,750 barrels per day of propane, isobutane, isopentane, natural gasoline and distillate.

In Texas also Gulf Refining Company is adding a polyform plant and a desulfurization unit to its Port Arthur refinery; Humble Oil & Refining Company is installing an MEK dewaxing plant at its Baytown refinery. TCC units are being constructed by the Lummus Company for Pure Oil Company at Smith's Bluff, Texas, and Lion Oil Company at El Dorado, Arkansas.

On the Pacific Coast Standard Oil Company of California announced early in the year that it contemplated capital expenditures of $33,000,000 of which $15,000,000 or more would go into the expansion of refining facilities at its Richmond and El Segundo plants. Two-stage crude units, each with a capacity of 35,000 barrels daily will be added to both refineries. They will handle the first step in the distillation of crude and will increase its utilization. The units are scheduled for completion by mid-year 1947. At El Segundo an SO_2 plant of 5,000 barrels daily capacity which is to begin operation late this year will increase the output of high grade kerosene and special products. The company also is greatly extending its research facilities and is spending $2,000,000 on buildings and equipment to be used in research activities which have been put under the direction of a recently organized subsidiary company. At Wellbridge, Oregon, near Portland, California Asphalt Company, a subsidiary of California Standard, is erecting an asphalt plant to supply the growing demand for industrial and road asphalts and is being completed at a cost of about $1,000,000.

Activities of the Tide Water Associated Oil Company include installation of a new topping unit at its Avon, California, refinery.

Shell's California activities include an expenditure upward of a million dollars in doubling Shell Chemical Company's output of ammonia and ammonium sulfate at Shell Point. A new office building also is being erected to accommodate the increased staff of the company. Near Portland, Oregon, an asphalt plant built by Bechtel Bros. McCone Company for Shell Oil Company is nearing completion. It includes an asphalt distilling tower, ten steel bulk storage tanks, a large concrete and steel building for storing barreled products and other office and warehouse purposes.

Perhaps the most interesting feature of Shell's expansionist plans is the enlargement of its research laboratories at Emeryville, California, already one of the largest and best equipped in the country. The increased space is needed according to President A. E. Lacomble of Shell Development Company to accommodate the growth of the staff which has doubled in size since the start of the war and will number 1200 when the present increase in personnel is completed. The expansion of facilities and working force is explained by President Lacomble as due to the transformation of refining from a simple processing operation into a complex and diversified manufacturing industry producing highly specialized petroleum products and large quantities of chemical materials formerly available only in limited volume at much higher costs. Architectural plans show that the largest of the three new buildings will be an eight-story structure with basement of steel and concrete construction built in the form of a square with ventilation ducts and elevators in the center and laboratory space around the perimeter. It will house the research laboratories.

The second major building will be a five-story addition to the present administration building. The third structure will be designed for heavy equipment. It will be of four stories and basement and will house the large-scale laboratory facilities and service shops. All buildings will be equipped with fluorescent lighting, sound proofing and special ventilation.

Nearing completion at General Petroleum's Torrance, California, refinery is a 15,000 B/D charge capacity delayed recycle coking unit being erected by the M. W. Kellogg Company. This unit had its inception under war construction planning to supply added olefins for alkylation unit charge and, as the major factor, gas oil to relieve critical shortage of such material for Navy Special fuel production. Both of these products, particularly the gas oil, will fill an equal need in peacetime operations owing to continued shortage.

Design is along conventional lines with dual low residence time heaters each delivering to separate pairs of coke drums together with necessary fractionating and gas handling equipment. Coke removal from the drums will be handled on cycle by hydraulic decoking. The unit may be alternately operated as a viscosity breaker by utilizing one of the drums as an unfired soaker.

Since this refinery processes up to 100,000 B/D, addition of such coking facilities will provide a high degree of flexibility in so far as maintaining middle distillate and heavy fuel balances. Construction of a 5,000 B/D Edeleanu plant will provide another addition to the Torrance refinery. This solvent extraction unit utilizing sulfur dioxide has been designed and will be constructed by E. B. Badger & Sons Company. With the impetus given by the war to manufacturing and transportation industries on the Pacific Coast, heavier demands are evidenced for railroad and automotive diesel fuels, aromatic and non-aromatic solvents, and burning oils of various grades. Production of the highest quality products of such nature, therefore, will be made possible to round out manufacturing operations.

The plant incorporates the latest improvements as developed over the years. Flexibility has been provided in the matter of tankage and services to permit ready manufacture of products mentioned in such quantities and when they may be desired. The plant itself must of necessity provide leeway in the matter of solvent to oil ratio as an added feature to permit production of such diversified products, each of the highest quality. It is expected that these facilities will be completed and in operation some time within the first half of 1947.

First catalytic cracking unit to be installed in Canada is being erected by Imperial Oil Ltd. at its refinery site in Montreal East. It is of the fluid type, of 11,000 barrels daily capacity. Design and construction is in charge of The M. W. Kellogg Company. In addition to the cracking unit the installation will include a pipe still of 13,500 barrels capacity and a polymerization plant.

In South America the volume of refinery construction now projected is greater than at any previous date in the industry's history. This is due in part to the inability of oil companies operating in that area to obtain materials during the war which not only barred the building of new plants but virtually prevented the making of needed replacements arising from obsolesence. In even greater degree, however, it results from the policy adopted by a number of countries of favoring or requiring that oil produced domestically be refined within their own borders.

In the revision of Venezuela's petroleum law in 1943 it was stipulated that companies holding exploitation concessions must refine 80 percent of their production within the country once their output reached proportions sufficient to support the operation of a refinery. Under the terms of

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[NO. 5 OF A SERIES]

The Proposition **Provision for recycling gas oil should be included in any design for Fluid cat-crackers.**

The Facts Passing any material through a given piece of process equipment more than once at less than the maximum performance level would not, at first glance, appear to be a most economical use of that equipment. However, in cat-cracking, if maximum cracking is attempted in one contact of oil and catalyst, undesirably high percentages of coke and dry gas are obtained in the cracked products.

Experience has proved that for optimum product distribution about half of the fresh feed should be cracked during the first contact with catalyst. Yet experience has also proved that for maximum overall return from feed stock about three-fourths of the average charge should be converted into light products.

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Thus for overall conversion efficiency . . . today and tomorrow . . . provision for recycling the gas-oil fraction is of utmost economic importance.

The Conclusion **There is no substitute for the *best* design.**

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the revised law, however, each of the four largest producers in Venezuela will have to construct refineries within the next three to five years and preliminary work on these plants already is under way as related in previous issues of WORLD PETROLEUM. One of these, projected even before the change in the law, is to be built by Cia. Consolidada de Petroleos, Sinclair subsidiary, at Puerto Cruz, terminus of the pipeline from the company's Santa Barbara field. It is designed for an initial capacity of 35,000 barrels daily.

On the Paraguayana peninsula, east of the Gulf of Maracaibo two large plants will be erected. One of these will be constructed by the Caribbean Petroleum Company, Shell subsidiary, at Punta Cardon. It will have a minimum daily throughput of 40,000 barrels and will require the clearing of a site, building of roads, wharves and a complete town with housing, health and recreational facilities for company employes. This phase of the work is now under way.

Creole Petroleum Corporation, affiliate of Standard Oil Company (N. J.), will build a 50,000 barrel daily plant on the shore of Amuay Bay, also on the Paraguayana peninsula, approximately 150 miles from the center of the company's producing operations on Lake Maracaibo. The site selected has the advantage of a good deep water harbor and crude will be transported to it by lake tankers. Construction is to begin shortly and the plant is expected to be completed by the end of 1948.

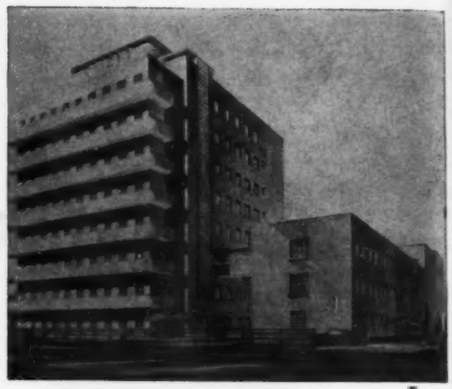
Mene Grande Oil Company, a subsidiary of Gulf Oil Corporation, also is scheduled to construct a refinery which probably will be of 20,000 barrels daily capacity and will be located at Puerto Cruz, terminus of the company's pipe line from the Oficina field. These plants will add upward of 150,000 barrels to Venezuela's refining capacity and will call for an investment of $150,000,000 or more.

A new factor has been injected into the Venezuelan refining situation by proposals placed before the government for the construction of a plant to handle part or all of its royalty oil. This project, said to be backed by independent oil operators in Texas appears to be regarded with some favor by the revolutionary government but has not advanced beyond the preliminary stage.

Plans for prospective additions to Colombia's refining facilities are likewise under consideration. A contract offered to the government by D. D. Feldman of Dallas, Texas, would call for the erection of three refineries to use as their crude supply the royalty oil accruing to the government under the concessions held by the various private companies operating in Colombia. The plans call for the building of pipe lines and the establishment of 185 service stations throughout the country. Such a contract would require the approval of the Colombian Congress to give it effect and consequently cannot be expected to be put into operation immediately. Reports have been in circulation in Colombia that two of the private oil companies contemplate the erection of refineries as soon as their production reaches sufficient volume but no definite announcement on the subject has been made.

Brazil heretofore has depended mainly upon imported petroleum products, having but two refineries, both in the south. The National Petroleum Council now has decided to authorize the construction of two more plants both in or near the capital city. One of these, Refinaria E Exploracao de Petroleo Unias S. A., will be built by Alberto Soares Sampaio and probably will be located on Ilha do Governador, just outside the harbor of Rio de Janeiro. Its initial capacity will be 8,000 barrels daily with provisions to increase this if market conditions warrant. The agreement requires that the work of construction shall begin within 30 days after final approval by the Council and that the plant shall be completed within two years.

The second refinery will be of like capacity and will be built under the same conditions by Drault Ernanny de Mello e Silva. It will be located within the Federal District and will be known as Refineria de Petroleo do Distrito Federal. One of the requirements laid down by the Council was that the projectors of new refineries must have an assured supply of crude before a concession would be granted. No statement has been made as what these arrangements are but it is assumed that the oil will come either from Venezuela or possibly in one instance from the Persian Gulf area and the names of prominent United States oil companies are associated with this phase of the operation.



Proposed new building to be used by the staff of scientists and the research laboratories of Shell Development Co. in Emeryville, Calif.

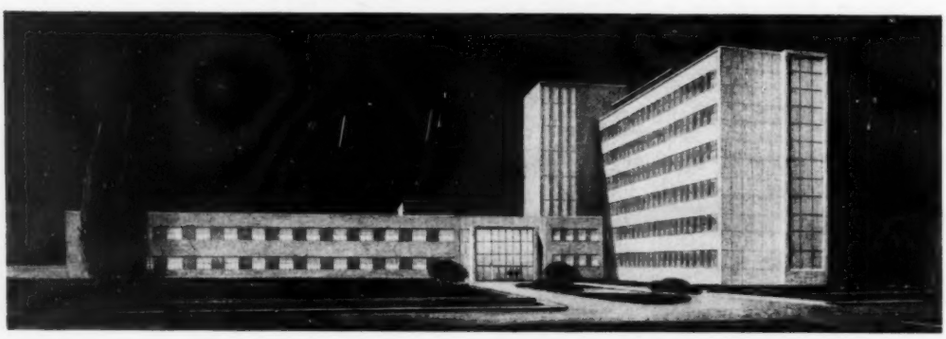
Inability to obtain materials and equipment has prevented the expansion that otherwise would haven taken place in Argentina's refining industry during the past six years. In 1938 Yacimientos Petroleros Fiscales completed the San Lorenzo refinery with a daily throughput of 9,500 barrels. In the following year this capacity was doubled and a combination unit installed at La Plata raised its capacity from 23,500 to 33,000 barrels daily. After that the intervention of the war halted further construction and the refining industry had to resort to many makeshifts to meet conditions that arose from time to time. YPF is now preparing to build in 1947 a refinery of 22,000 barrels daily capacity for a full line of products. At the present time samples of the crude to be treated are being tested to determine the equipment best suited to handle it. Plans for a catalytic cracking installation to produce high octane gasoline are under consideration by one of the privately owned refining companies.

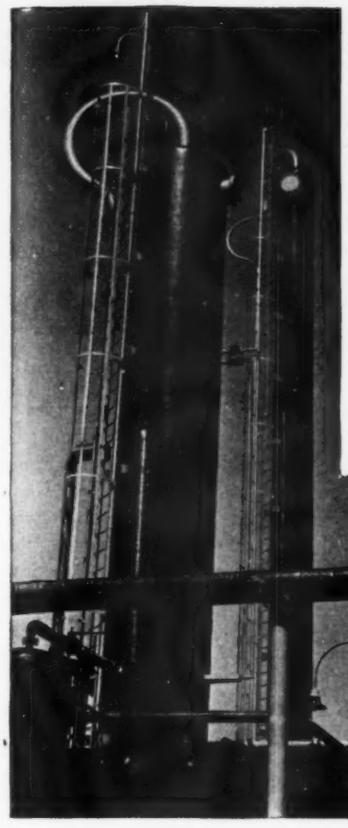
Stimulated by the discovery of production in its southernmost area the government of Chile, through its Corporacion de Fomento, is giving thought to the establishment of a refinery of 10,000 barrels daily capacity with thermal cracking equipment. The refinery would handle crude produced within the country and would supplement this supply to whatever extent necessary with imports, probably from Peru.

Bolivia's plans for expansion of its oil industry include the erection of a modern refinery at Sucre to process 5,000 barrels of crude daily and to produce gasoline, kerosene and fuel oil. Its crude supply will be drawn from Camiri and its transportation will necessitate the building of of a pipe line 250 miles long which probably will be the highest in the world.

Altogether the refinery program of South American countries calls for the greatest amount of new construction ever undertaken and will give the refining operations of that continent far greater importance than they ever have had.

New headquarters planned for Standard Oil's Whiting refinery.





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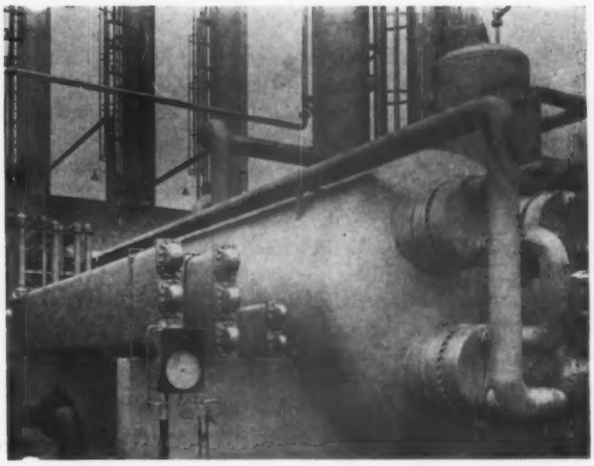

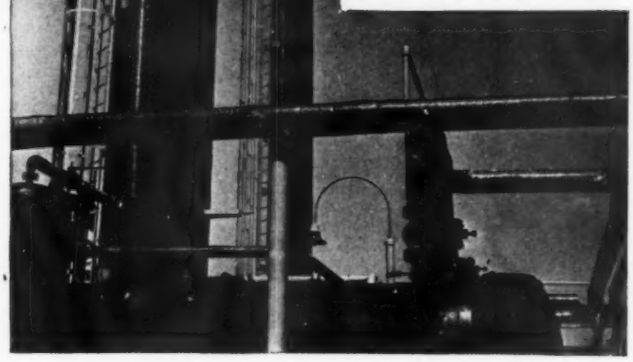

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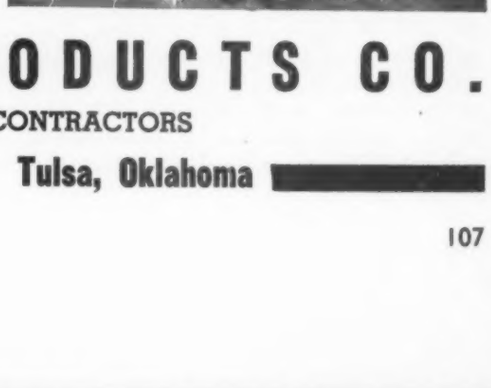

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In Europe and also in those parts of the Far East overrun by the Japanese the immediate problem before the refining industry at the close of hostilities was the repair of the damage inflicted during the war and the restoration of plants to full or partial production. The experience of British refineries during the long period of enemy bombing is told elsewhere in this issue. In France the refineries in the northern part of the country suffered severely first from the blowing up of essential parts under French military orders in the face of the German invasion and later through intensive bombing by American and British planes. Most of these plants now have been put into partial operation as a result of temporary repairs. The Port Jerome refinery of Standard Francaise des Petroles, located in northern France on the Seine River between Havre and Rouen, was put into operation in February of this year, after being inoperative since the early days of the war. This refinery ran prewar approximately 25,000 barrels daily of crude, largely of Venezuelan and Iraq origin, and produced a full line of products including lubes and asphalts. The tankage was almost completely destroyed in June 1940 under orders of the authorities so that it would not fall into the hands of the approaching German armies and the refinery remained inoperative throughout the remainder of the war in Europe.

Shortly after the termination of hostilities, work was resumed on the rehabilitation of the refinery and progressed to such an extent that in February of this year it was able to resume operations at slightly less than half of its prewar rate. It is now running approximately 10,000 barrels daily of crude on a skimming basis, and it is anticipated that by the end of the year the throughput will be increased to some 12 to 13,000 barrels daily, that cracking operations will be resumed, and that lubes and asphalts will be produced. Later, as materials become available, it is anticipated that the refinery will be restored to its prewar capacity.

The experience of this refinery is fairly typical of conditions encountered by refineries in northern France. In the southern area plants sustained little damage during the war and are operating to the extent permitted by limited transportation facilities and short supplies of crude.

Before the war Italian refineries had a throughput capacity of 12,500,000 barrels per year but all plants suffered injuries during the conflict ranging from a crippling of certain units to complete destruction. A recent survey indicated that refining operations during 1946 would be reduced by possibly 60 percent giving perhaps 500,000 - 600,000 barrels against estimated requirements of 19,000,000 barrels. To fill the deficit the Italian government has been making efforts to arrange for the importation of products but it is doubtful that these can be obtained in sufficient volume to meet even the present limited demand.

Reconstruction of Italian plants has been delayed by the impossibility of obtaining materials and equipment and by the uncertainty of the country's political status. With the establishment of a stable government (at least such is the hope) and the assurances given by the authorities that a free market will be maintained and the rights of both foreign and native investors respected the oil companies are now in a better position to plan for the reconstruction of their plants.

Being under Nazi domination and little molested by air attacks the Austrian refineries have been able to maintain operations and at latest reports six or seven plants were in operation producing about 15,000 barrels daily. Plans for the improvement of foreign owned plants are waiting upon a determination of the conditions under which Austria will resume its place as an independent nation.

No settled policy has as yet been adopted by the occupying powers in regard to Germany's oil industry. Refining plants of sufficient capacity to handle Germany's crude output presumably will be kept in operation but this will provide only a fraction of the country's prewar consumption. Following the German surrender it was announced that all synthetic plants would be destroyed or removed and a survey with this in view was undertaken by the American and British military governments. In the Russian zone, however, it is reported that one large synthetic plant is in operation and under a recent commercial agreement some of its products are to be shipped to other zones. Under existing conditions no plans for refinery rehabilitation are being considered.

Though badly damaged during the war repairs to cracking units of the Pernis refinery of Bataafsche Petroleum Company in Holland have enabled it to resume operation pending subsequent enlargement. Sweden's refining facilities are to be increased by the erection of a second plant by A. Johnson & Co., at Malmo, now approaching completion. There has been discussion also of a proposal for construction of a refinery by Swedish cooperatives but no final decision appears to have been reached. In Poland, Czechoslovakia and Yugoslavia oil has been made a government monopoly. The question of reimbursement to American and other owners of refining plants is now under discussion and no announcement has been made as to governmental intentions regarding replacement of equipment.

The Romanian oil situation was described recently in WORLD PETROLEUM. Many of the country's refineries were partly or completely put out of commission by systematic air attacks during the latter part of the war. New equipment is badly needed but has been unobtainable and only makeshift repairs have been possible. Foreign owned companies operating there are anxious to retain their position but their outlook is uncertain.

The Soviet Union lost its western refineries during the Nazi invasion including plants at Odessa, Swastopol and Krasnodar. Meanwhile, new plants have been constructed at points further east with equipment obtained from the United States during the war. The extensive Russian program for increased oil production calls for the construction of several new refineries as soon as the needed materials are available.

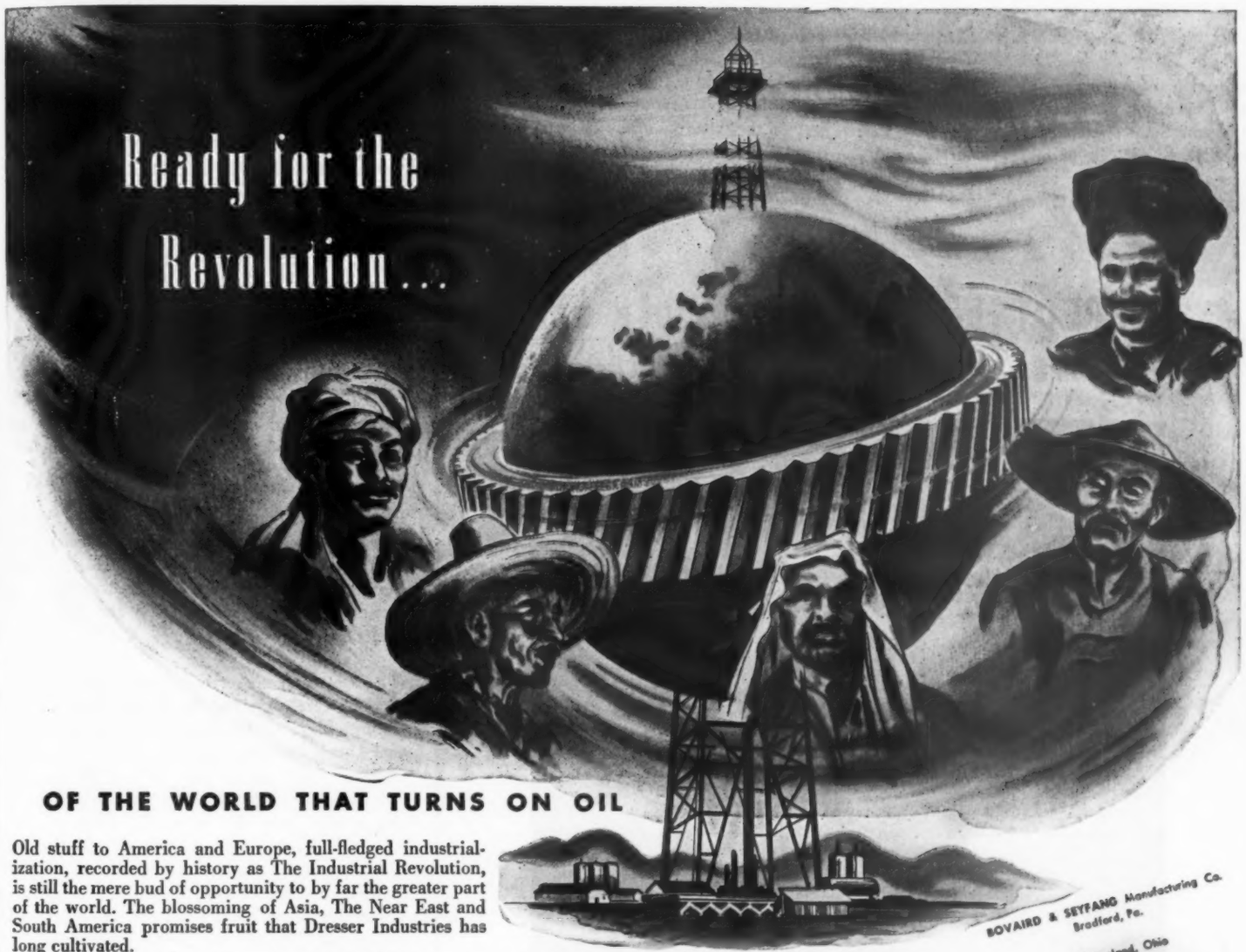
Refining capacity in the Middle East was greatly expanded during the war by expansion of the Abadan refinery of Anglo-Iranian Oil Company described elsewhere in this issue and of the Haifa plant of Consolidated Refineries which was doubled to meet military needs. During this period also the new plant of Arabian-American Oil Company at Ras Tanura and of Bahrein Petroleum Company on Bahrein Island have come into operation. During the past year both these plants have been running far above their rated capacity, producing mainly gasoline and fuel oil, much of the latter for naval use. With work under way on the construction of additional pipe lines which will triple the output of Iraq Petroleum Company further enlargement of the Haifa refinery is to be undertaken. The government of Iraq has revived its plan for construction of a state-owned refinery to process its royalty oil and reported to be designed for a throughput of about 8,500 bbl. daily at Baiji, on the Tigris, 80 miles south of Mosul. These plans, which are in the hands of the London organization of Foster-Wheeler, are said to involve expenditure of about £1,500,000 ($6,000,000), but as the project is still in the embryo stage no details of plant are available.

A scheme of this kind has been talked of since before the war, but Iraqi finances kept it in the background until recently. Iraq has the advantage of an ample supply of crude on the spot, but the scheme to supply internal needs from a state-owned refinery seems to be based on considerations of political prestige rather than economic necessity.

Iraqi petroleum requirements have so far been mainly for fuel oil for the railways and irrigation machinery, although consumption of kerosene and motor spirit recently has been increasing. The demand has been met hitherto by Anglo-Iranian from its refineries at Khanaquin and Abadan as provided in its contract with the government.

Further east in the area that formed the theatre of the Japanese war virtually complete reconstruction of the refining industry is made necessary by the fact that nearly all the plants in this region suffered partial or complete demolition during the course of the conflict. Plans for this

(Continued on page 116)



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WORLD REFINERY CONSTRUCTION ENTERS NEW STAGE

(Continued from page 108)

restoration have been drawn up by the companies operating in this area with the exception of Japan. Some plants are now working at part capacity. In the case of others disturbed conditions surrounding their locations or inability to obtain materials has delayed the start of reconstruction.

The Burmah Oil Company's refineries at Syriam, Rangoon, with others in the same area and the oilfields and pipe line installations, were for all practical purposes completely destroyed as part of the "denial" measures instructed by the British government and taken early in 1942 to prevent the integrated petroleum industry of Burma from falling into the hands of the Japanese.

It has only recently been announced that compensation for these losses must await official assessment. To delay rehabilitation until then would defer the contribution the Burma government expects, and the industry itself is anxious to make, to the economic and general recovery of the country. Accordingly, the industry, relying on equitable and reasonably speedy satisfaction of legitimate claims, is pushing ahead with execution of plans for reconstruction which have been under close examination during the enemy occupation and since. Resumption of refining in accordance with these plans cannot, however, be expected for some considerable time.

It is reported that the Attock Oil Company may build a new refinery to process oil from the Joya Mair field in the Punjab, India, because of the special character of the production which is a highly viscous black oil with a specific gravity of 0.950 and is difficult to treat with conventional refining equipment.

The principal producing region in the Pacific area was comprised within the East Indies where practically all refining plants were badly damaged either by deliberate "scorched earth" tactics or by bombing, sometimes by the Allies and sometimes by the enemy.

The most extensive refining operations in this section were those of the Royal Dutch-Shell group. Its crude production in Java, Sumatra and Dutch Borneo amounted to 143,000 barrels daily in 1939, out of total production for the area of 194,000, the whole of the production being refined near the fields. In addition, the Group had production in Sarawak and Brunei. Plans made in advance at the request of the military authorities assured the destruction of the refineries, with wells and oilfield equipment, before the Japanese occupation. The Japanese did a good deal of work in an attempt to re-

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store production and refining capacity, but before their surrender in August 1945 some of the fields and refineries were again damaged, either by Japanese or by Allied bombing.

Meanwhile, preparations had been carried on for a considerable time to restore production and refining. A military task force of trained oil technicians and a supply of materials had been assembled in Australia for this purpose. Its first operation was concerned with Tarakan, Dutch Borneo, the first oilfield to be liberated in May 1945. There is no refinery at Tarakan, the crude produced there being either used in its natural state or refined at Balikpapan. This center was liberated shortly after Tarakan, and it was found that the refinery and much auxiliary plant and equipment had been almost completely destroyed. Two distilling units were found to be repairable fairly easily and a range of products will shortly be produced, although lack of storage is a great handicap.

In Java, Royal Dutch-Shell had two refineries, at Tjepoe, near Rembang, and Wonokromo, near Sourabaya. Tjepoe refinery was severely damaged, and political unrest prevents an estimate as to when it will be fit to restart. Owing to the sudden collapse of Japanese resistance, the refinery at Paladjoe, southern Sumatra, fell into Allied hands before any serious damage had been inflicted, and at that time was considered to be in much better shape than the Java refineries. As the oilfields in the area had also been largely restored by the Japanese and had not sustained subsequent damage, production at Pladjoe should be resumed as soon as political conditions permit. The refinery at Pangkalan Brandan in northern Sumatra, which was demolished in February, 1942, was subsequently rebuilt gradually by the Japanese. Latest reports indicate that this plant may be able to resume output at about two-thirds of its original capacity, but surveys by an expert staff were interrupted by political disturbances, and the staff had to be withdrawn. An account of the war experience of the great Palembang refinery of Standard-Vacuum Oil is the subject of an article on other pages of this issue.

A small addition to the refining facilities of the Asiatic continent is the Kansu plant at Lao-chun-miao near the Yemen field in Kansu province, China, which has a crude charging capacity of 3,600 barrels daily. The Chinese have formulated extensive plans for the expansion of production and refining both on the mainland and in Formosa and recently have arranged for surveys by American engineers to determine suitable locations for plants to be constructed.

Bitumen and Australian Oil Refineries, Ltd. has been organized with a capital of $5,000,000 to build a refinery in Australia. California Texas Oil Company will subscribe to 40 percent of the capital stock with the remaining 60 percent of the stock to be owned by Australians. Crude will be brought to the plant from the Persian Gulf. Plan is to make Australia more nearly self-supporting as far as refinery products is concerned.

★

Announcement . . .

Robert W. Duden, President of Petroleum Equipment, Inc., takes pleasure in announcing the association of F. D. Morgan, J. Howard Kinslow, and T. C. Cannon with this organization as of July First, 1946.

Morgan and Kinslow were formerly with Lucey Products Corporation as co-managers of the Steam, Power, and Heating Division, and T. C. Cannon served under them with the same company. Their new duties with this organization will be the establishment of a similar department in addition to assisting in handling the rapidly expanding business we are now enjoying.

We consider ourselves very fortunate to be able to make available to you the services and knowledge of each of these men, and we know that we shall be able to better serve you by making this addition to our present organization.

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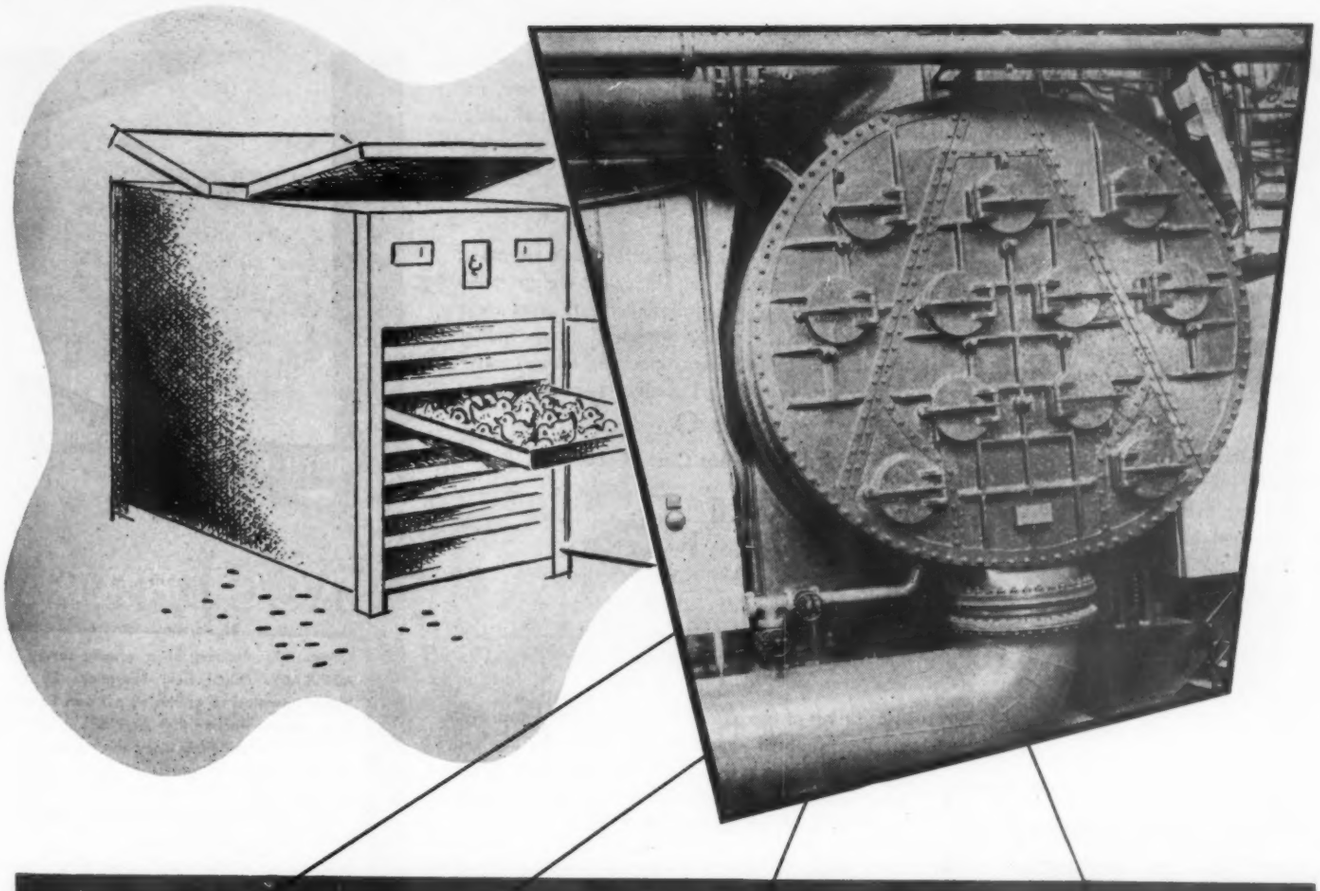

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Cycloversion For The Small Refiner

(Continued from page 70)

naphthas, in separate streams or as a blend of either high or low sulfur content with resultant octane improvement up to 20 points at the 3cc TEL/gal. level, depending on the nature of the stock. Attendant operating losses are usually of the order of 5-15% basis C_3-lighter to fuel gas. Carbon deposition is low as compared to heavy oil feed stocks and range from 0.25-0.60 weight percent of charge. Such low carbon deposition permits process cycles of 24 hours or more and low catalyst regeneration costs.

The catalytic treatment of a gas-oil naphtha blend has been investigated with results indicating improvement over that of a blocked operation of the naphtha and gas-oil in separate streams. In addition to an improvement in octane levels, such an operation results in increased yields greater than that obtainable through separate processing.

The fixed-bed feature of the Cycloversion process, together with the extremely rugged nature of the natural, low cost catalyst, renders it most economical for up-grading of refinery motor fuel stocks with increased yields. The fixed-bed design offers several advantages in that mechanical maintenance costs and catalysts replacement cost are low.

Operating costs for the Cycloversion of gas-oil stocks are approximately 18.3c/bbl. charge, while for gasoline range naphthas operating costs are of the order of 6.0c to 10c per barrel charge including, among other things, operating labor, catalyst regeneration, utilities, insurance and maintenance.

Refinery Cost Higher

Creole Petroleum Corp. has revised its cost estimates of the new refinery which is to be built at Paraguana, Venezuela. Originally the 60,000-barrel refinery was to have cost $50 millions but W. J. Connelly, manager of Creole's manufacturing department now estimates that the cost will be $65 millions.

Beginning of construction waits on final approval of the proposed site. Until recently the favored site was Amuay Bay but final approval of the site depends on facilities which the company receives from people of the area.

Included in the Creole project is the construction of a town of 2,000 homes capable of housing up to 10,000 people. This phase of the program is the largest yet undertaken in Latin America by any industrial company.

Elected Kellogg Vice President

E. F. Liebrecht has been elected a vice president of the M. W. Kellogg Co. He has been general patent attorney for Kellogg since 1940. He was a patent attorney representing the interests of major oil companies and their affiliated patent licensing companies prior to joining Kellogg. In his new position he will have complete administrative direction of the company's patent activities and the handling of all licensing for the Company and its associates.

Announcement

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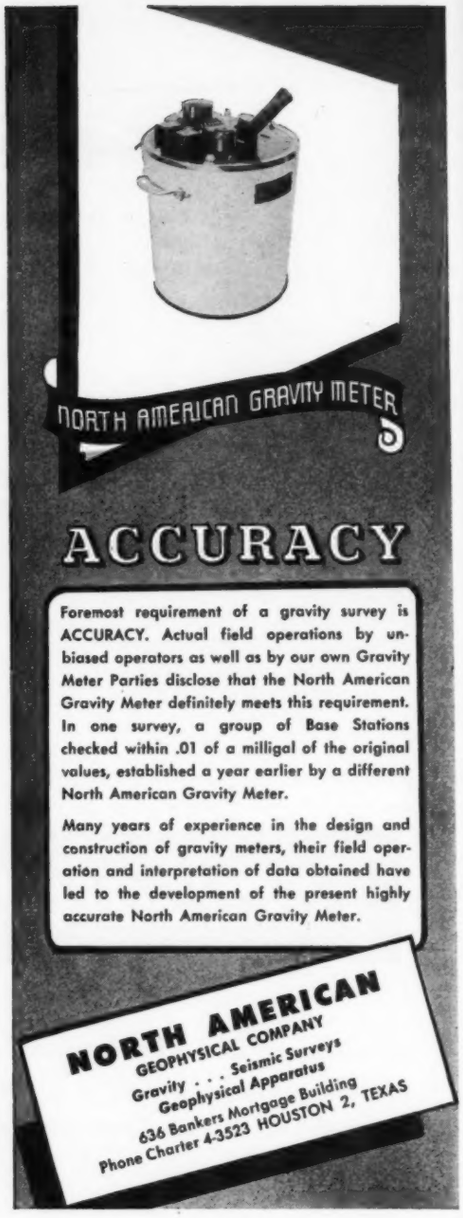
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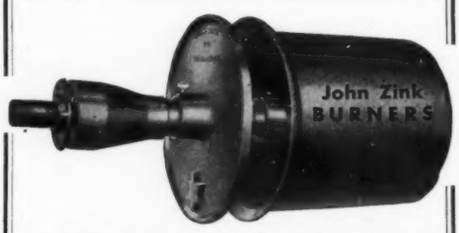

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GULF OIL CORPORATION — **GULF REFINING COMPANY**

Demand Forecast

(Continued from page 93)

very high residual fuel oil yields obtainable. This was brought out in the discussion of residual fuel oil requirements. Some imported South American crudes are required to produce economically quality asphaltic products as many of these crudes have a particular value in this respect. It is also natural to expect that several of the American companies, having made large investments in South American crude oil production properties, plan to utilize a portion of these newly found supplies by bringing them into the United States for processing. The refinery facilities for doing this are at present built in the United States and if this were not done, it would simply mean that duplicate facilities would have to be built in some foreign countries in order to refine these crudes into usable products. All of these considerations were taken into account in the estimate of crude imports indicated.

It is also indicated that during 1946 there might be a requirement for increases in crude stocks amounting to 19,000 barrels per day of production. This was predicated upon a consideration of prewar inventory levels of crude oils. A complete study of this subject was made by the writer for the American Institute of Mining and Metallurgical Engineers which was printed by them in May, 1945, (Technical Bulletin 1870) under the subject "Post-War Inventories of Crude Oil and Petroleum Products in the United States." Graphic presentation of crude oil production is shown in Graph 4.

Percentage Yields from Crude Runs to Stills

Table No. 14 shows the percentage yields which the industry has run in the prewar period and 1944 as well as the indicated yields which would have to be accomplished in order to balance supply with demands forecast. These yields have been adjusted, of course, to take into account products that are estimated to be made from natural gasoline, condensate and benzol, the amount of crude oil which would be used directly as fuel as well as the No. 1 fuel oil which would be used as kerosene and the imports of residual fuel oil. By applying these adjustments to the total demands the yields were calculated.

It will be noted that in the post-war period at no time does the yield of gasoline amount to as much as the recent pre-war yields. Kerosene yield is slightly above prewar but when consideration is given to the fact that a much larger proportion of the crude available during these years would be of a non-kerosene type of crudes that can make kerosene only at relatively high costs, these yields may require a higher percentage of kerosene from the remaining crude. The total yields required for so-called "middle distillates" is shown to increase in the post-war period, but still seems to be within refining limits as the total yield of these products amounts to only 23.4 percent in 1950. Nevertheless, this increase will create some industry problems and a new consideration of product evaluations. These yields may be slightly understated as mentioned previously due to the fact that some unanticipated diesel oils required for buses and trucks may come into the picture and add a small fraction to these requirements which would be deducted from gasoline requirements. The residual fuel oil yield is about the same as was indicated in previous articles and is in line with the effect of catalytic cracking on the yields as forecast by W. G. Moore of the Gulf Oil Corporation in a paper entitled "The Effect of Catalytic Cracking Upon the Post-War Supply." This article came to the conclusion that the yields of residual fuel oil would probably be reduced two percent from the pre-war yields and this is just about what our calculations indicate for the requirements. The reason for the very large yield required for 1946 is that immediate demands by the Navy and the War Shipping Administration are exceedingly large and the inventories on hand at the beginning of the year were much below normal. Both of these conditions indicate a requirement above normal for this year. From then on the yields required decline continuously. These residual yield requirements are after allowing for importation of residual fuel oil as indicated in Table No. 14. The yields for asphalt and road oils are substantially about the prewar requirements and this is allowed for through the importation of substantial quantities of asphaltic crudes from South America which would make it possible to obtain these high yields.

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